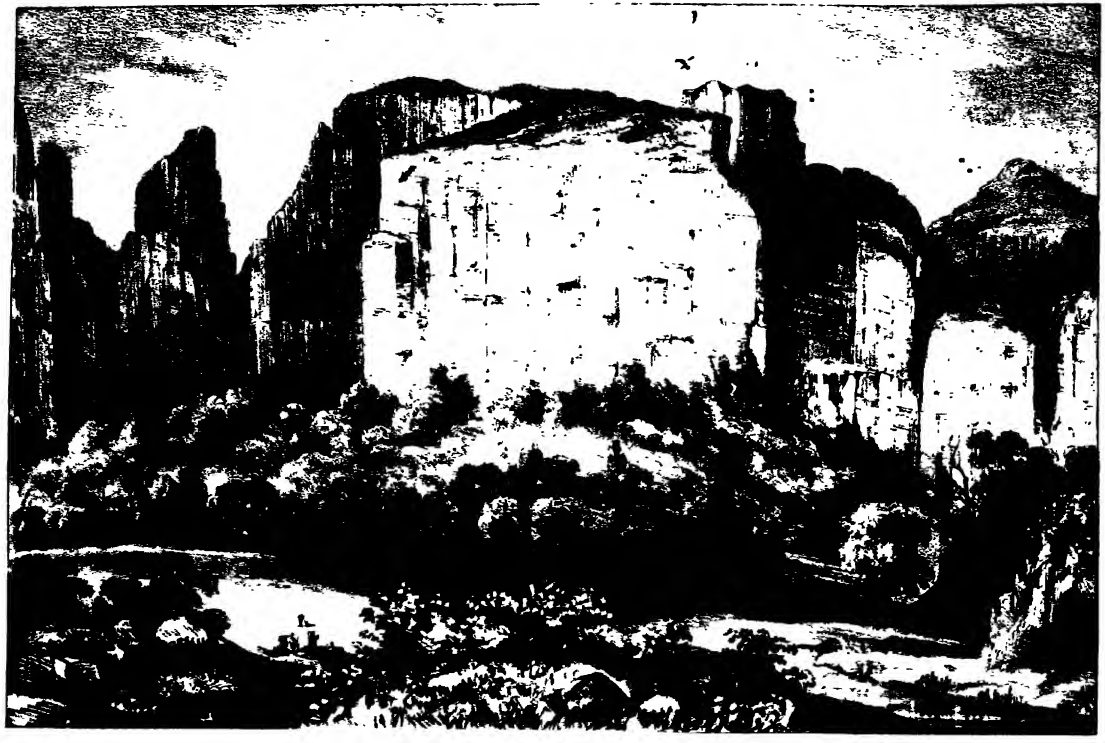
MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.



W. L. Fraser Lith Calcutta

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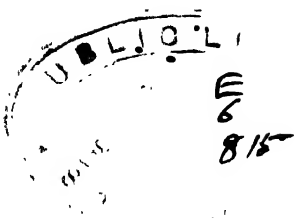

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UNDER THE DIRECTION OF

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On the Geological Structure of the Central portion of the NERBUDDA *District by* JOS G. MEDLICOTT, A. B., *Geological Survey of India.*

(Introductory note by Mr. Oldham.)—In submitting the following report, a few words of explanation are necessary. In the Autumn of the year 1854, the examination of the Rajmahal district being then nearly completed, it was decided that the Tenasserim Provinces should be visited, with a view to ascertaining the amount of coal and other mineral wealth which they possessed; and that, at the same time, the district of the Nerbudda should be examined with a similar object. I proceeded myself to the Tenasserim Provinces, and with the aid of my active colleague, Mr. William Theobald, Junior, was enabled to visit, and report upon, the more important mineral districts of those territories, and also of the lower part of the Irrawaddee valley. Subsequently I accompanied Major Phayre on his mission to the court of Ava, and was then enabled to map and describe the country along the river Irrawaddee, to a distance of some 70 miles above the capital of Burmah. The Nerbudda party meanwhile proceeded to their district, under the charge of Mr. Joseph G. Medlicott. The temporary assistance of his brother, Mr. Henry Medlicott, then recently appointed, from the Geological Survey, to the Professorship of Geology at Roorki College, was afforded to me by Government; and with these two Geologists was united Mr. John S. Kennedy, a young gentleman of much promise, but who had just arrived in the country, and was quite untrained.

During the limited portion of that season which remained after their arrival in the district, a general preliminary examination of the coal fields in the Nerbudda valley was accomplished, and a brief report on the whole by Mr. Jos. G. Medlicott was submitted. (*a*) After a few months

(*a*) Selections from the Records of the Government of India, No. X.

Mr. H. Medlicott returned to resume his duties at Roorki. During the following season (1855-56,) illness, which to our great regret terminated fatally, deprived the Survey of the services of Mr. Kennedy, and Mr. Joseph Medlicott was then, for a short time, alone. I proceeded there myself, at the close of the year 1855, and took a general review of the whole district. The results of this visit, combining my own and my colleague's observations, were briefly published in May 1856.*(a)* I also reported to Government on the coal and iron districts of part of the valley. At the close of the working season, I returned to Calcutta ; Mr. Medlicott continued working out in detail the structure of the country. During that season he succeeded, in mapping topographically, as well as geologically, the country extending from Lokurtullye on the west, to the parallel of Futtehpur on the east, and taking up his quarters during the monsoon at Jubbulpore, he examined, with some care, the immediate vicinity of that station. Again taking the field early in the season of 1856-57, he completed the area now mapped eastwards to the neighbourhood of Sohagpur. During that season, Mr. Theobald was sent to his assistance, and was requested to devote his attention more especially to the recent deposits of the valley, from which he obtained an admirable collection of Fossils, now in the Geological Museum, Calcutta.

At the close of that working season (Spring of 1857), Mr. Medlicott proceeded to Calcutta, and thence accompanied me to Europe, on duty connected with the Geological Survey and Museum. Mr. Theobald, who had gone to the station of Mhow, for the monsoon, escaped from the hands of the mutineers with considerable risk, and reached Bombay in safety, with only the loss of some of his property.

It had been my intention to have resumed the examination of these districts at once, during the next working season, (1857-58) but the disturbed and unsafe state of the country at that time, rendered this quite impracticable. In consequence of this there are, as will be seen, many points of great interest still unsettled, which nothing but the careful examination of the extension of the same rocks to the eastward, along the valley of the Soane river, and into the Rewah territory, can solve. And it would certainly have been more satisfactory to all concerned in

(a) Journal Asiatic Society Bengal, Vol. XXV, page 249.

the investigation of the geology of this district, if this could have been accomplished, as was originally intended, previously to attempting any general description. Meanwhile, however, it seemed desirable to publish at once what was known, and to leave the correction of errors, or the addition of facts, to some future time. Sufficient has been done to shew as we think, that these future researches will not materially affect the great features of the classification here adopted, while much of valuable detail undoubtedly still remains to be worked out.

With great pleasure I take this opportunity of bearing testimony to the zeal and intelligence which my colleague and assistant, Mr. Joseph G. Medlicott, has devoted to the work entrusted to him. The valuable Map which accompanies this Report, and which is almost entirely the result of his own unaided surveys (with some contributions from Mr. Theobald along the river itself,) sufficiently attests my words. European Geologists seldom realize fully the difficulties which attend the steps of their brother labourers in this country. Districts without maps, without roads, without supplies, without inhabitants, meet you frequently. To go where you wish is often simply impossible, and you must only rest content to go where you can. The most malarious and deadly parts of the jungle are often those which give the best, or perhaps the only sections visible. Seldom is it possible to return to the same place a second time, to correct an error, or supply an omission. The most marked and prominent features of the country, to which you trust as landmarks to fix accurately your position, are not uncommonly sources of confusion and perplexity, as you find the same peak known by different names, from different sides, or by different people, a fact which you only discover after long and tedious cross-examination.

These difficulties are not stated here, as affording any excuse for errors, although they might fairly be accepted as a palliation of deficiencies. Nor do I think such need be urged in the present case inasmuch as Mr. J. Medlicott has, with very trifling assistance, mapped, and successfully examined geologically, an area of about 8,157 square miles. (*a*)

(*a*) This includes the whole area of the larger Map, of which however, a considerable portion is covered by the valley alluvium.—Topographically, about 5,625 square miles may be considered as a compilation, 2,532 being from original sketch surveys.

In drawing up the following report on this district at large, he has, of course, had free access to the labours of his colleagues, Mr. William Theobald, Junior, his brother, and myself, and has combined the results of all; but to his own exertions are due by far the larger portion of the valuable facts detailed below.

It is satisfactory to find that the more recent, and more extended examination of the district by Mr. Medlicott, has resulted in fully confirming the general outline given in 1856 of the principal facts in its Geological structure. In some respects the rough sketch I then hastily gave, has been corrected, and many important features have been filled in; but on the whole, these changes have been far more in the nature of additions, than of alteration. The great groups of the Mahadeva and Damūda on the one hand, then first announced and established by myself, and of the Vindhyan on the other, which the brothers Medlicott had separated during the previous year, remain now, as then, the key to the structure of the country: this being the earliest attempt made to reduce to order the confused mass of sandstones, shales, &c., which had previously been all jumbled into one great heap of anomalies.

The sectional diagrams given in illustration are chiefly from Mr. Medlicott's note book; the sketches showing the general features, from my own.

T. OLDHAM,

Supdt. of Geological Survey of India.

CONTENTS.

CHAPTER I.—PRELIMINARY NOTICE OF THE WORKS OF PREVIOUS OBSERVERS.

(Geological papers.)—That portion of Central India which is included in the Maps published herewith, has for many years attracted the attention of Indian Geologists.

The great variety of the rocks there exposed, the picturesque beauty of many parts of the country, and the early discovery of fossil remains, probably led to this. It has therefore been thought desirable to preface the following report by a brief sketch of the principal labors of our predecessors: as well to do justice to the excellence of many of their observations, and to the zeal with which their explorations were made, as to enable the reader to see how far the Geological Survey has followed, where differed from, and how added to, the conclusions at which these earlier observers had arrived.

1823. Capt. Dangerfield.

The earliest published notice of the Geology of Central India, of the existence of which we are aware, is by Captain Dangerfield, and is appended to Sir John

Malcolm's "Memoirs of Central India," published in 1823.* This paper, full of accurate statements, evidently the result of careful observation, confines itself to descriptions of the lithology and mineralogy of the district.

Many of the rocks are well described, and the localities where they occur, mentioned; and a Map accompanies the work, showing the general boundaries of the area occupied by each. The date of the paper (1823) will, to a Geologist who remembers the state of the science at the time, sufficiently explain why Captain Dangerfield's results were not based upon any geological classification now recognised; nor would Captain Dangerfield's paper convey to the mind of the geological reader of the present day any very definite ideas of the structure of the country he examined, and which he described from the point of view of a disciple of Werner.

1828. Franklin.

A few years later (1828) Captain Franklin contributed to the Asiatic Society of Bengal, and also to the Geological Society of London, a valuable memoir on the Geology of Bundelcund. In this he chiefly enters into the discussion of the Geological relations of the rock masses; he identifies the sandstones of the Table-land with the central portion of the New Red System of England, principally it would seem, on the strength of some saliferous deposits which were stated to belong to the group. He describes also the limestone of the Rewah plateau, and alludes to fossil ferns, silicified wood, and a gryphæa, from its beds. His collections have, unfortunately, been lost, and no one, since that time, has been able to find any organic remains whatever in these rocks. Captain Franklin also described the crystalline rocks of the Nerbudda valley, and discussed their relations to the granite, stating further, that the latter, sometimes although not always, underlies the sandstones of the plateau, without the intervention between the two, of any of the bedded crystalline series. He notices two

* *Loc. Cit.* Vol. II, page 313.

varieties of trap rocks, considering one to be contemporaneous with the metamorphic rocks, the other to be overlying, and of the epoch of the calcareous conglomerate and tufaceous deposits, evidently of an origin more recent than the sandstones. A map and sections exhibiting the writer's views of the Geological structure of the district were also given.

1829. Hardie.

In the following year Mr. Hardie brought before the Asiatic Society of Bengal *(a)* a description of some of the rocks of the same district, confining his attention, however, to a limited area. His remarks also, are more directed to the mineralogical or lithological structure of the rocks, than to their geological relations.

1833. Jacquemont.

Jacquemont visited this district a few years later and corrected, in several respects, the statements of Captain Franklin. He points out the absence of all "primitive rocks" at the base of the escarpment at Tara-ghat, where Franklin had represented them to occur. He gives detailed descriptions of the rocks of the Rewah Table land, especially of the limestone, in which he was disappointed at not being able to detect any traces of those organic remains mentioned by his predecessor. He describes this limestone as resting on the sandstone of Kuttra-ghat (the second range) and underlying that of the Bundair hills (the third range), at the same time saying, that he did not succeed in finding any section clearly showing that this latter superposition obtains.

The main value of the labors of this naturalist on the geology of this part of Central India seems to be derived from the care with which he observed and the minuteness with which he described, as a mineralogist.

Captain Franklin states that he found "black bituminous shale in all the glens," on the north side of the Bundelcund plateau; Jacquemont mentions the presence of "Anthracite" near Rampur, and both seem to

(*a*) Sketch of the geology of Central India, exclusive of Malwa, by James Hardie, Esq., Asiat. Resear. Vol. XIX, pt. II. p. 27.

associate the presence of coal with these rocks. Doctor Carter indeed quoted their authority to this effect, but although careful search has been made in the localities mentioned by Captain Franklin no true carbonaceous deposit has as yet been rediscovered there, or in any other part of the great area occupied by the rocks of this series.

Captain Franklin, as has been stated, refers the sandstones of Bundelcund to the age of the European Trias, and Jacquemont (in part at least) endorsed his views. But even supposing that this opinion should ultimately prove to have been a correct one, it must still be regarded merely as a happy guess, for these authors advanced little tending to suggest, and nothing sufficient to maintain, such an hypothesis.

1833. Everest.

The Rev. J. Everest gave a few years later, in a paper published in the journal of the Asiatic Society of Bengal,(*a*) some observations on part of the same country. He described the sandstone and trap rocks, and defined some of their boundaries, without however materially adding to the facts of Franklin and Jacquemont.

1834. Finnis.

Lieut. Finnis described the country between Nagpur and Hosungabad. He noticed the prevalence of trap south of Betul, from thence to the valley at Shapur, he found vertically bedded schists, quartzites, and mica slate; from thence to Kesla he observed sandstones with carbonaceous shale, among which Col. Ouseley had in 1832 (1827 ?) discovered coal. He noticed intrusive trap, and speaks of recent calcareous conglomerate and tufa.

In the range crossed from Kesla to Patroda he mentions crystalline limestone, quartzite, and other metamorphic rocks, and from all these he separates the sandstone which he found at Hosungabad, and which he agrees with Captain Franklin in calling New Red: distinguishing it, however, from the sandstone he saw between Shapur and Kesla.

(*a*) Jour. Asiat. Soc. Bengal, Vol, II, p. 475.

He also mentions the presence of recent conglomerate in the Nerbudda. In this excellent paper the author gives good descriptions of many of the varieties of rock which he found along this very varied section.

1834. Spilsbury.

Dr. Spilsbury, who has done so much for the palæontology of Central India, published also two papers on the Geology of parts of the district.(a) He states his conviction that the bone-bearing sandstone and conglomerate form a wide spread deposit, and he considers as portions of this, beds seen at several localities far removed from one another, as at Birman Ghât, in the Dudi Nala near Gurrurwarra, and in the Nerbudda bank at Hosungabad.

He observed that the coarse conglomerates seen at the base of the hills near Futtehpur, pass upwards into the sandstone which is interstratified with calcareous bands. He describes, as he passes southwards, many varieties of sandstone and a fine trap-dyke seen in the Deinwa River. From these sandstones of the glens, he distinguishes, as to mineral character, the massive beds of the Mahadeva hills.

In the second of the papers(b) alluded to, this author gives an account of his journey to Umurkuntuc. He points out how the old crystalline rocks between Mandla and Umurkuntuc occupy the low grounds towards the south-west, and are everywhere covered up towards the north-west, by Basalt and the "inter-trappean" deposits.—Also how he finds on descending from Umurkuntuc towards Sohagpoor, sandstone which on the plain below is associated with carboniferous beds, and is covered on all the heights, by traps with the inter-trappean shelly chert, and shelly limestone bands; and how these bands may be traced along the base and lower slopes of the hills; and he gives a list of localities where fossils abound in these beds.

He also concludes that coal crops out somewhere in the vicinity, from finding a fragment of this mineral in the shingle of the Johilla, where he crossed this stream.

(a) Jour. As. Soc. Bengal, Vol. III, p. 388.—(b) Ibid, Vol. IX, p. 889.

Dr. Adams describes the rocks of Bundelcund, taking up the area north of that concerning which Dr. Spilsbury wrote; the same nearly as that which was the subject of Captain Franklin's paper. He comes to the conclusion that the thickness of the Vindhyan sandstone is small; he also speculates on the manner of the formation of the limestone seen near Lohargaon, which rock he believes to be of comparatively recent origin.

1842. Adams.

Some of the Geologists, whose work we have quoted, pass, as has been shown, from the field of observation to that of speculation, and portions of the rocks of Bundelcund have been referred to the Old Red Sandstone, to the Lias and to the Trias respectively, as their European equivalents. Such hypotheses, quite unsupported as they were by evidence, have naturally proved of little value. Yet having been advanced by men who had at least seen the rocks which they describe, these hypotheses were consistent as far as they go, that is, they group together beds which closely resemble each other, and which are conformably stratified. This can scarcely be asserted of the theories contained in Dr. Carter's* work on the Geology of India. It will perhaps have been remarked that all those Geologists above quoted as having written on the structure of that part of the country with which we are at present concerned, seem almost entirely to avoid all those geological questions which relate to the physical condition of the rock masses: such as the manner of original formation, of subsequent disturbance, of denudation, &c., and also those questions which are concerned with the relations of one series or group of rocks to any other such series, such as the superposition of one of these on another, and the conformity or unconformity of such superposition where it exists; and thus Dr. Carter unfortunately had not at his disposal that kind of information on the geology of the country which

1854. Carter.

* Jour. Bombay As. Soc. Vol. V, p 179: also reprinted with notes in "Geological papers on Western India" 1857, p. 628.

would appear indispensably necessary to the success of an attempt such as he made in his "Summary." This circumstance accounts for the presence of the extraordinary statements of which it is made up in the portion which treats of this part of India. It would seem indeed almost to be regretted that the indomitable industry and great power of classification and combination of which this work gives proof, as well as the scientific reputation of its author, should have stamped with authority and given currency to generalizations which possess absolutely no other recommendation.

It would be out of place here to enter into any detailed examination of Dr. Carter's valuable Summary, which is well known to Indian Geologists, and it will suffice to refer to a few of the points on which the Geological Survey are at issue with that author.

The first of these will naturally strike any Geologist coming from the Ganges Valley towards that of the Nerbudda, when he reaches the Kuttra Ghât. Dr. Carter assumes the "Kuttra Shale" to be the representation of the Burdwan Rocks, and of carboniferous strata in other parts of India. As there is no fossil evidence to appeal to, this identification must necessarily rest on lithological grounds, and would certainly never have been made had the theorist ever seen rocks of the two formations which he identifies, and which are strongly contrasted in many ways. Again, Dr. Carter under "Punna Sandstone" includes the escarpment rocks north of Hosungabad with those on the opposite side of the valley, there forming the north-east boundary of the great trap area of West India. Lieutenant Finnis, who described these rocks twenty years before, did not confound the Sandstone north and south of the valley, nor could any one who had even superficially observed them, have fallen into this error. Both certainly are stratified, both sandstones, but here all resemblance ends.

As a subdivision No. 2 of the group of "the Kuttra Shales" Dr. Carter gives *limestone*, and under this head a somewhat incongruous

assemblage of rocks is marshalled, namely the Sagur Shell-limestone noticed by Captain Nicholls; the crystalline limestone of Bhera ghât; and the Lohargaon, and Rewah limestone. His reason why these should have been grouped together it is very difficult to imagine: the rocks are as unlike each other in lithological aspect as is well possible. The presumption would certainly be that the first is "intertrappean," the second has been well described by Captain Franklin as "altogether unconformable" to the sandstone of the Bundair Range, and whatever may be the exact Geological age of the third mentioned rock, it is unquestionably intermediate between that of the first and second.

1855. Hislop.

Mr. Hislop has mentioned in his memoir "on the age of the Coal strata in Western Bengal and Central India,"(*a*) some of the rocks included in the area which forms the subject of the present report. He speaks of the carbonaceous shales, &c. to the south of the Mahadeva hills, and identifying them with similar beds found near Nagpur, and again near Kotah, he points out their connection with those rocks known to contain coal in the Damūda valley, and comes to the conclusion that all belong to the same age. Subsequent examination of the localities mentioned has tended to confirm his conclusions. It has also, however, introduced a line of separation between the lower and the upper rocks of the Mahadeva section near the Mahadeva hills, considered by Mr. Hislop as all belonging to the same group.

1856. Schlagintweit.

Messrs. Robert and Adolphe Schlagintweit have both noticed the rocks of this district. Mr. Robert Schlagintweit describes the bone deposits of the Nerbudda noticing the occurrence with the bones,(*b*) in brown alluvial clay, "of shells of Unio, Melania and the fresh water species." But he

(*a*) Jour. As. Soc. Bengal, Vol. XXIV, p. 347.

(*b*) Report VI and VII of Magnetic Survey of India.

appears to have entirely overlooked the occurrence of fossil bones in the other deposit near Jubbulpore, which is of totally different character and age. Mr. Adolphe S. describes the sandstone of Bundelcund and Gwalior as *absolutely identical* with similar rocks in the Nerbudda Valley, at Nagpore, near Trivicary in South Arcot, &c., &c., and thinks the coal strata of Raneegunj also the same. It will be seen that the conclusions arrived at by the Geological Survey are totally different.

(*Mineral resources.*)—Besides the more purely scientific memoirs above quoted, there has been much written on the mineral resources of this part of India, where coal and iron have long been objects of research and observation. Colonel Ouseley seems to have been the earliest as well as most successful explorer of coal, of whose labors we have any account on record. In 1827(*a*) he discovered the Sonadi seam as well as that near Murdanpur, and in 1832 he found some coal near Futtehpur. In 1835(*b*) he described the coal in the Sita Riwa river near Mopani, as well as that exposed by the Hurd river above Hutnapur, and although he in every case took a perhaps too favorable view of the commercial value of these localities, yet with him remains the merit of having first pointed out the places where the mineral was to be found, and of drawing to the subject the attention of Government and of the public.

1827. Ouseley.

With this view, he in 1838 sent 206 bullock loads of the Mopani coal to Bombay, where it was tried in the dock-yards, and after comparison with some of the well known standard coals of Europe, its value as a fuel was determined and placed on record. We may here add that if the reports and papers given to the public by the many observers who since Col. Ouseley's time have visited the Nerbudda Valley be examined, it will be found that not one of them has added one valuable locality to those which he named, or one useful observation to those contained in his description.

(*a*) Jour. As. Soc. Bengal, Vol. III. p. 395 —(*b*) Ibid. Vol. IV. p. 648.

In 1839(*a*) Spilsbury brought to notice the seam of shale seen at Lameta ghât near Jubbulpur, greatly exaggerating its capabilities, and in the report of the Coal Committee for 1845, this bed is spoken of as "a very large bed of coal many yards in thickness and of first rate quality," with a second bed 400 yards down the stream, 6 feet thick. This shale has been the subject of some curious exaggeration which may be given as a specimen of the information current on the subject of the mineral resources of this part of India.

1839. Spilsbury.

In Dr. Carter's "Summary" the following passage appears at page 667. "Ansted in his Elementary Geology under the head of "Jubbulpur" states, 'that, at nine miles from the station, there is a bed "of first rate quality (coal) many yards thick, crossing the bed of "the Sone;' the nearest part of the Sone to Jubbulpore is forty "miles distant, so this would appear to be the largest bed yet dis-"covered."

A reference to the Coal Committee Report for 1845, page 178, shows at once that Professor Ansted copied these statements, in which *Sone* had been misprinted for Nerbudda, a mistake not likely to be corrected by a writer in England. But to any one familiar with Indian geography, it would certainly have appeared more probable that some error in the statement had occurred, than that a bed of coal stated to have been observed nine miles from the station of Jubbulpur should, in reality, cross the Sone, the nearest point of which was forty miles distant. But without any inquiry whatever into the grounds of Professor Ansted's statement, and apparently from the tendency of Indian Geologists to exaggerate everything supposed to be favorable to the existence of valuable mineral resources, we find the statement accepted at once, and a bed of coal of "first rate quality" and "of many yards thickness" stated to exist over forty miles, and the somewhat amusing remark added, that this is "the largest bed yet discovered."

(*a*) Jour. As. Soc. Bengal, Vol. VIII, p. 530.

In 1844-46, Mr. Rammel, an accomplished engineer, connected with Messrs. Hunt and Co., of Mirzapore, sunk pits and shafts on the Lameta ghât shale, in hope that what was rubbish at the outcrop might prove cleaner inside; but he was soon obliged to abandon it as useless: yet this is the subject of the above remark of Dr. Carter. Much of the work of reporters subsequently to Col. Ouseley's time, has been based upon data similar to the above, and elaborated in a similar spirit, and each one in his turn has *discovered* any of the previously known localities which he had time to visit. Moreover, their measurements are not generally more accurate than those of the original explorer.

Mr. Johnson, in 1848, worked the Sonadi seams successfully, under the instructions of Sir Robert Hamilton: he confirmed Col. Ouseley's measurements, and was successful in getting coal of good quality to the surface, but the difficulties of carriage put an impassable barrier to the undertaking.

Mr. Jacob, in 1854,* speaking of the same place, Sonadi says that the "three seams which outcrop, though of little value, are sufficient indication of a rich seam beneath," an assertion unsupported by the slightest evidence: he adds that "the available coal measures will be about 15 miles long by 7 wide." Abundant proof might be adduced against this latter statement; it is indeed difficult to conceive on what ground it was made. At Mopani, Mr. Jacob speaks of three seams of coal outcropping close together near the village of Berar: he failed to perceive that a small fault causes the outcrop of the beds (of which only two exist) to be repeated at the surface. He saw both outcrops of one of the beds, and one of those of the other, but the second appearance of the second had escaped him, nor did he see a locality decribed by Col. Ouseley a mile down the stream, where another bed occurs.

* Selections from Records of Bombay Government, No. XIV, p. 136.

In 1847, Mr. Blackwell repeats all Mr. Jacob's mistakes, makes three beds out of the two, and overlooks the second locality altogether.

In 1855, a paper descriptive of the physical character of the Nerbudda by Dr. Impey, accompanied by selections from public correspondence, and other papers relating to coal, &c., of the district, was published in the Selections from the records of the Bombay Government, (No. XIV) and a map of the river accompanied the paper. The accuracy of the contents of this volume on the subject of coal may be gathered from the fact, that out of eleven localities marked on the map, three have been placed on parts of the country occupied by Crystalline rocks, *viz.* schistes or granite, where of course no coal exists, and that *in every case* where measurements of the coal beds marked have been given, the thickness has been considerably exaggerated. As above remarked, Col. Ouseley's descriptions have been little, if at all, improved upon, and have sometimes been even misquoted, while no new locality has been added to his list. Below will be found a new list of all localities now known, with carefully made measurements of the thickness of the beds seen in each, the date of discovery, and name of each explorer. The more systematic researches of the Geological Survey naturally made them acquainted with some outcrops not before known; but among many such, only one gives fair promise of remuneration to mining enterprize.

Iron.

The Iron of the Nerbudda valley has also been very carefully examined and very fully reported upon. When Colonel Pressgrave in 1830 opened his suspension bridge over the Beos river near Sagur, he did more to place in their true light, the mineral resources of the district, than any amount of purely scientific investigation could do.

His statistics, and those of Captain Franklin, together with the detailed experiments of the latter, gave the fullest information on the subject of the capabilities of Tendukhera and of some other Iron-producing localities. Mr. Jacob, and lastly Mr. Blackwell, have

carefully experimented and laboriously collected information, and Professor Oldham's report (extracts from which will be found below) on the subject seems to have exhausted the question, and sums up all the information which we need possess preparatory to such experiments on a large scale as commercial undertakings are likely to be prefaced by, and which Colonel Presgrave has shown to be at least practicable.

Palæontological Papers.—In 1830 Colonel Sleeman discovered fossil bones in the Jubbulpur limestone breccia, and in 1833,(*a*) Dr. Spilsbury sent to Calcutta some fossils from that locality, as well as from several places on the banks of the Nerbudda and its tributaries.

1830. Sleeman.

In the same year Dr. Spry(*b*) sent down to Calcutta his first set of specimens of the fossil shells from the vicinity of Sagur, and described in a paper to the Society the manner of occurrence of these shells, and of some silicified trunks of palm trees, which he states to have been found in the same bed with them.

1833. Spry.

The bones procured from Colonel Sleeman's locality, that is from the limestone "bone-breccia" of Jubbulpur, were so imperfectly preserved as to be found incapable of affording to Mr. Prinsep any evidence sufficient to determine the animals to which they had belonged; but those sent by Dr. Spilsbury from the Omar Nuddi, Segauni, Birman ghat, and Hosungabad, were described as femora of an Elephant, skull of Buffalo, &c. From the neighbourhood of Sagur and Jubbulpur, from many of the above mentioned localities in the Nerbudda Valley, and from several new sites discovered principally by Dr. Spilsbury, considerable numbers of specimens of many kinds of organic remains were sent down to Calcutta during the next few years.

In 1834 Mr. Prinsep(*c*) enumerated a considerable variety of these

(*a*) Jour. As. Soc. Bengal, Vol. I, p. 456.—(*b*) *Ib'd.* Vol. II, p. 549.—(*c*) *Ibid.* Vol. III, p. 396.

Central-Indian, fossils, among them the remains of Horse, Elephant, and Buffalo, and in 1839 Mr. Frazer and Dr. Spilsbury(*a*) gave a list of fossil localities known to them up to that time, along with drawings by Captain Reynolds of several fossil shells.

The same gentleman subsequently furnished drawings of some fossil bones from Hosungabad and Heerapur: these were Buffalo, Elephant, and Hippopotamus. Again in 1841 Dr. Spilsbury (*b*) sums up the results of his labours, gives some more drawings, and a list of animals whose remains he had disinterred, which includes *Hog, Hippopotamus, Elephant, Ox, Deer,* and *Turtle,* and perhaps *Palæotherium.** Again in 1844(*a*) the same indefatigable explorer published drawings of some bones from wild and domestic animals, for comparison with the fossils.

In these papers very few stratigraphical conditions were investigated.

In 1834, in a query addressed by Mr. Prinsep to the Geologists of Central India, he asks if the bone-bearing gravel of the Birman Ghat is ever overlaid by the black cotton-soil, and if its formation, and the fossilization of its organic remains, might not be due to the proximity of the hills, the lime-charged water of springs rising among which may have indurated an ossiferous alluvium. The fact is that the bone-bearing beds are always overlaid by, and never overlie the Regur, and are part of a deposit widely spread over the valley, the great area which they occupy showing that they cannot be referred to local causes such as calcareous springs. It was also asserted(*b*) that the ossiferous limestone of Jubbulpur rests conformably on the sandstone beneath. Subsequent observations prove this not to be the case.

(*a*) Jour. As. Soc. Bengal, Vol. VIII, p. 950.—(*b*) *Ibid.* Vol X, p. 626.

* The fossil here called Palæotherium has since been shown to be Hippopotamus (Hexaprotodon.)

(*a*) Jour. As. Soc. Bengal, Vol. XIII, p. 765.—(*b*) *Ibid.* Vol. II, p. 583.

Much yet remains to be done with the fossils thence brought together, and large undescribed collections now exist, from the study of which important information will doubtless be elicited.

In all the papers published regarding these however, it has never been doubted that they were all derived from deposits of the same age, and it remained for the survey to point out how entirely different in position and period the bone-breccia of Jubbulpur and the bone gravels and clays of the Nerbudda Valley are.

In the preceding remarks also, a few other points have been noticed in which the results of the detailed examination of the country by the Geological Survey differ materially from all preceding views,—and the details of these will be found below. The chief points of the difference were first brought forward by Professor Oldham in 1856, and as, while farther examination has added to the knowledge we then possessed, no material change has been introduced in the classification hitherto proposed, it may be well here simply to state some of the results.

1st.—The entire group of Sandstones, Shales, &c., of Bundelcund and Rewah which lie north of the River Nerbudda, (or more correctly of that part of the River Nerbudda included in our map,) the great scarp of which rocks is well seen along that valley as well as that of the Sone, was separated totally from the Sandstone Rocks associated with coal, &c., which occur to the south of those rivers, and with which it had previously been confounded: to this great group the name of Vindhyan was applied, as being best seen in the Vindhyan range. The probable cause of that remarkable scarp was also pointed out.

2nd.—The thick Sandstones of the Mahadeva and Puchmurri Ranges which form such bold escarpments and pointed hills to the south of the river, were also separated from the coal-bearing rocks on which they rest.

3rd.—The passage upward of these Sandstones into the rocks containing remains of large Vertebrata was pointed out.

To this classification, more recent and detailed examination has enabled us to add the sub-division of the Damūda into two groups upper and lower, and has thrown much light on the relations of the trap flows and the associated beds.

Of the evidence on which those conclusions rest, we shall now proceed to speak.

CHAP. II—GEOLOGICAL STRUCTURE OF THE DISTRICT.

§ 1. *Physical Geography.*

Area mapped.

In addition to that part of the valley of the Nerbudda which lies between Hindia on the west and Jubbulpur on the east, the map which accompanies this report, also includes the Gondwarra range on the south of the river valley, as well as a small area stretching to the north-east from Jubbulpur to the Johilla River, one of the principal affluents of the Sone.

Connection of the Physical with the Geological structure.

The Nerbudda taken altogether, from the source of the river to the sea, constitutes one of the most important and interesting features of the Physical Geography of Western India, and in no part of the valley is its peculiar and characteristic configuration more strikingly exhibited than in that portion included in the accompanying map.

It will be shown hereafter, that this peculiar configuration of the present surface of the ground is the direct result of Geological structure, and it has consequently been thought desirable to reserve a detailed description of the physical aspect of the country and of the relations which this aspect has to Geological causes until after the various rocks

shall have been described. It will nevertheless be convenient, by way of introduction, very briefly to refer to some of the principal and more marked of these physical features.

The Vindhyan escarpment.

Of these the great rock escarpment of the Vindhyan hills running along the north side of the valley is unquestionably the most striking.

This range of flat-topped cliffs is marked by great uniformity of outline averaging from 300 to 400 feet above the level of the valley, in rare cases rising to 800. It is however incorrect to speak of this as a range of hills. Seen from the south it presents an almost uninterrupted series of headlands with projecting promontories and receding bays, like a weather-beaten coast line; but these form the abrupt termination of a table land and are not an independent range of hills. It would be difficult to point out a finer example of cliffs once formed by the denuding action of shore-waves, but now far inland, than is exhibited along this range. From the summit of these cliffs however there is no descent to the north, corresponding to their southern declivity: on the contrary, the plateau is found to stretch away in this direction in gentle undulations. The northward slope, though slight, commences from the very edge of the escarpment, and a reference to the map will show that the Betwa, the Dessaun and the Sonar Rivers have their origin in places overhanging the valley of the Nerbudda. In one or two localities where the latter river in its winding course flows close to the north side of its valley, the southern limits of the drainage area of the Ganges may there be seen to reach to within little more than a mile of the actual main stream of the Nerbudda.

The Mahadeva escarpment.

On the south side of the valley, the hills present a more broken and less regular outline than on the north. Instead of an uniform range of escarpment like that of the Vindhyan hills, we here have irregular groups of hills of different heights and different forms of contours, and which are composed of different rock.

Similar groups of hills or broken ranges occupy the greater part of the country commonly marked " Gondwara Hills" on the maps. The elevated area of this hilly country, considered as a whole, culminates in the mass of the Puchmurri group of peaks, whose grotesquely shaped summits, and bold perpendicular faces are visible from great distances in most directions, and form a very conspicuous feature in many fine landscapes.

These lofty hills stand at some distance back (to the south) from the Nerbudda valley, and are well within the Gondwarra hill district. The hills between them and the Nerbudda seldom reach any considerable elevation, and never, at any point along the whole range, equal the Puchmurri peaks in height. Of these hills of the outer range, Chatur Doria is one of the highest, and is nearer to the Puchmurri group than any other peak of considerable altitude; but it stands rather within than on the outer range. Nimbnaghur, however, a few miles to the east, stands immediately over the valley and rises nearly 1,300 feet above it.

The valley itself.

The valley proper, as defined by the two ranges of high ground to which we have just referred, is of very variable width, and consists (throughout that portion with which we are concerned) of a slightly undulating plain, broken here and there by an occasional low hill. It is covered with an extremely rich soil, and is mostly under cultivation. Throughout the length included in our map the fall of the rivers is trifling when compared to that which occurs in the part of its course east of (that is above) Jubbulpur, or in that portion below Hindia on the west.*

Great variety of rocks.

It of course follows, from the fact of the summits of the Vindhyan escarpment forming, as we have stated, a drainage boundary, that the Nerbudda is itself principally fed from

* Further details concerning the flat ground of the valley, its Physical Geography, and its Geology, will be given hereafter.

the south side, and accordingly the map shows that, within our area, all its chief tributaries flow in from this direction. These streams after escaping from the gorges of the Gondwarra Hills, have hollowed out channels for themselves across the flat ground of the valley beyond, exposing throughout most of their course, many rocks distinct from each other in age, and differing among themselves in lithological character. And whether among the hills, or in the plain beyond, the various texture and structure of these rocks, as well as their diverse modes of occurrence and of disintegration, have impressed on the landscape that endless variety of outline, from which its principal charm is derived.

Some Geological boundaries.

The great escarpments north and south of the valley, above mentioned, are no doubt sufficiently remarkable when considered simply as physical phenomena; but they become still more interesting when, as is found to be the case, they are known to coincide with geological boundaries.

The north escarpment.

Thus the Table land of Malwa and Bundelkund is formed of the sandstones seen in the Vindhyan escarpment, and described in the following pages under the name of "Vindhyan Sandstones," a group of rocks not known to occur any where south of this line of the north escarpment of the Nerbudda valley, at least not within the area mapped.

The south escarpment.

In a similar manner the line of escarpment bounding the valley on the south, marks the northern limit of a series of rocks, which will be found described below, as including those formations called in our lists "Talcheer," "Damuda," "Mahadeva," &c., and no rocks belonging to any of these groups are known, within our area, to occur north of this line of escarpment.

The Trap.

On both sides of the valley the high ground is often occupied by Basaltic Trappean rocks. On the north such rocks spread into wide patches over the country

towards Bhopal, Sagur and Dumoh, in which direction they gradually die out (see Plate II;) on the south and south-west the Trap is found to cover considerable areas among the Gondwarra hills and it becomes gradually more and more the prevailing surface rock in this direction, and, so far as known, connects itself with the great Trap area of the Deccan.

Other rocks exposed.

Besides the rocks already mentioned several other vareties exist. Granitic and gneissose rocks and crystalline schists are exposed in many places in the banks of the Nerbudda, in those of its numerous tributaries, and in many other parts of the valley, sometimes covering considerable areas, and often forming prominent features in the scenery of some of the most picturesque parts of the country.

Classification.

The classification made use of in the following pages will be that proposed for the rocks of Central India by Professor Oldham in 1856 (see above page 115). The differences between the following list, and the series as then given by Mr. Oldham will be found to consist of one or two additions. These are subdivisions introduced among the groups then indicated, but not changes in their arrangement; they are developements of the original sketch, not alterations of it.

In our descriptive remarks, we shall commence with the granite and reserve the trappean rocks for the last, and with the sedimentary deposits we shall proceed in ascending order.

§ 2. *Granitic Rocks.*

Area occupied by granite.

Rocks of granitic type, although often seen at the surface, do not occupy large areas in this portion of Central India: the largest of these areas is found near Jubbulpur where the granite forms a range of low hills running from Lamèta Ghat on the Nerbudda in a north east direction.

Near where the old town of Gurra stands, the hilly area of the granite is about two miles wide, and a building now in ruins, called the Muddun Mehal (Fig. 1) stands on the highest point of this part of the range. The sketch shows the general aspect of the rocks here, which may

Fig. 1. View of the Muddun Mehal, at the western extremity of the granite hills near Jubbulpur.

be taken as typical of that of the granite of the country. From this place the granite may be followed for many miles to the north east, forming a narrow irregular band among the Metamorphic rocks: it is not even quite continuous but sometimes thins out and disappears for a short space, coming to the surface again in the same general direction. This line of

the granite is approximately parallel to the strike of the metamorphic rocks. though not absolutely so. Whenever we find the igneous rock near to the altered bedded formations, their relations seem equivocal, a definite line can rarely be drawn between the two, and the transition from one to the other is often imperceptibly graduated.

Nature of granite boundaries.

Lithology of the Granitic Rocks.—The mineral characters of rocks included under this head are in our area very various. That variety which is most widely spread and occupies the greatest extent of surface is a porphyritic syenite whose matrix is a mixture of glassy quartz with pale pink or pale green felspar, along with a small proportion of hornblende, and which contains embedded crystals of dull lead grey felspar (adularia) about one-third of an inch long, and in great number, frequently forming a large proportion of the mass.

Porphyritic syenite.

A rock answering more or less closely to this description forms the Gurra hills (see ante, Muddun Mehal Fig. 1)—much local variation in the composition of the mass obtains, and this sometimes to the extent of totally altering the general aspect of the rock. Thus, the adularia crystals are sometimes altogether absent, elsewhere they become so numerous, as to constitute of themselves two-thirds of the rock mass; again, minute crystals of black mica are found replacing the hornblende, and were in one case noticed along with it, in a hand specimen; sometimes the rock becomes fine-grained syenite without any detached crystals and with very little quartz. A good case of this occurs at the second bridge from Jubbulpur on the road thence to Sohagpur where the hornblende is in unusually large proportion.

The hills near Hinotia village S. of Nursingpur are mostly made up of this syenite porphyry; here the detached crystals are of pink felspar.

Below Hosungabad much granite is exposed in the banks of the Nerbudda, and here also it is mostly either this syénitic porphyry with pink felspar, or a pink

Red felspar granite.

felspar granite; this latter is the rock seen at Hindia. A similar red felspar granite forms a range of hills in the southern portion of the country surveyed, and is also well seen in the Sita Riva section near Berkera.

Pegmatite.

In several places in the Southern part of the country examined, a very beautiful pegmatite has been observed. Near Poplia Village a large spread of it occurs, it is composed of bright pink felspar in large crystals, and embedded in clear colorless glassy quartz; here and there through the mass little specks of black mica are scattered and patches of a pale green mineral occur irregularly. The stone is a very beautiful material and will some day be used for ornamental purposes, both the *pattern* traced by the crystals, and the colors, combining to produce a very fine effect.

Syenitic Porphyry with red felspar.

In the valley of the Johilla River, in Sohagpur district, a variety of the metamorphic rocks, very characteristic of that series is largely developed in connection with a syenitic porphyry, somewhat like the general description above given. Here, however, the felspar of the base, or matrix, as well as that of the detached crystals, is red, the crystals themselves being much larger than is usual and also more numerous; many of them exceed 2 inches in length, and in places form of themselves more than half the mass. Here a part of the section exposes a rock which might readily be mistaken for one of sedimentary origin but which is really part of the granite of this last mentioned variety. The felspar crystals have, from some local cause, all arranged themselves with their longer axes parallel, and a completely laminated aspect is the result. This is however soon seen not to have been caused by a deposition or arrangement of the crystals by water, for, close examination shows that the crystals are really embedded in a crystalline mass as well as quite angular and not rounded, and the character is itself very local, parallelism soon ceasing to exist, and the normal irregularity of arrangement obtaining again.

Pseudo-gneissose character.

In the immediate vicinity a very gneissose schist is found, closely resembling this pseudo-laminated syenite in parts, although on the whole an unequivocally bedded rock.

Sher Nuddi.

In the Sher Nuddi near Sehora, a similar gneissose schist occurs, characterized by red felspar, and in places retaining but very feeble indications of its bedded structure. In this place although there may have been an intrusion of a molten rock to a comparatively small extent, yet the general character of the mass is proved, by the recurrence of layers of different mineral character, to be bedded, and lamination is developed as well in the most highly crystalline portions as in those where the sedimentary character is most clearly seen.

Pink-felspar granite and gneiss in Talcheer conglomerate.

The presence of fragments of all these remarkable pink felspar rocks, both schistose, and granitic, in the "Boulder bed" of the Talcheer group, (see below) is very characteristic of that formation, throughout this part of central India. The same fact was noticed by the Messrs. Blanford in Cuttack.*

Pegmatite of Nagpur.

The pegmatite above mentioned is unequivocally part of the granitic rocks of the country, and is, as has been asserted of the group generally, anterior in formation to the deposition of the lowest section of those sandstones and shales, included under the names Talcheer, Damuda &c., in our list. Further to the south, however, somewhat different relations are stated to obtain between these formations, for Mr. Hislop, speaking of the "Pegmatite of Nagpur city," says (Quarterly Journal of Geol. Soc. London. Vol. xi. p. 381) "that it has upheaved the very highest member of the Jurassic sandstone," that is, we suppose the upper Damuda or perhaps Mahadeva sandstone of our classification. The complicated structure of the rocks where Mr. Hislop describes them, has perhaps

* Memoirs of Geol. Survey of India, Vol. I. p. 37.

suggested to him that this pegmatite may possibly be subsequent in origin to the trap (the overflowing trap of the district). Nothing however seen within the area of our map would bear this interpretation.

Only one granite period.

Instead of our having reason to suppose that any portion of the granite of this area can be referred to an age posterior to that of the overlying trap, all the evidence goes to show that the whole of the granite seen belongs to the same geological era. The only observed fact tending to suggest a different conclusion is the existence of veins in the granite of the Gurra Hills; but these are probably veins of segregation rather than intrusive; besides these being intrusive would be quite insufficient to establish the existence of granite of two distinct geological ages.

Age of the granite.

Considering the granite then as all belonging to one Geological era, it was subsequent in origin to the schist rocks as is evident from what is seen in the following sections.

Salibanta Section.

One of the minor tributaries of the Tawa River exposes a section near the village of Salibanta, 8 or 10 miles south east of Shapur (on the Hosungabad and Betul road) where several fragments of hornblende schist are completely enveloped in a granitic mass; the granite has apparently been forced among the beds of the gneissose rock which are seen broken and contorted in contact with it and intensely *altered* in its immediate vicinity.

Jelounda Section.

In the Nerbudda between Jelounda and Hindia, a mass of granite is seen which breaks up the beds of the schistose quartzite and encloses large fragments of it.

Granite subsequent to the Schists.

In each of these cases the bedded rock is unquestionably part of the metamorphic schistose series of the district, and the granite in each is clearly traceable to some of the great granitic masses, and the latter is, in both, palpably more recent than the former which, as has been stated, is altered in its vicinity. A few

similar examples have been observed in which the granite seen to cut up and alter the schist is clearly a part of the characteristic granite of the country and where as far as such evidence can go, it seems fair to conclude that the period of the advent of the granite was subsequent to consolidation of the schists. The more common case however is such as that furnished in the Gogra Nuddi section* where many granite veins traverse in every direction the schist beds, but where the schist, though of course probably part of the similar series seen elsewhere, *might* be almost anything, and where the granite veins have no apparent connection with any mass of granite. Such examples though incapable of being used as evidence, certainly tend to confirm the conclusion above stated, that the granite is more recent than the schists.

When however in ascending the geological section we come to examine the Sub-Kymore and Vindhyan series† no facts similar to the above are found, nor can we in the present state of our knowledge with certainty say that the granite of this district is older or newer than these rocks.

It has no where been seen to disturb the beds of either of them, nor, on the other hand, have the latter ever been any where observed to rest on granite, or to contain pebbles presumably derived from it. Still though no positive evidence can be adduced to show that the granite period was anterior to the deposition of the Sub-Kymore slates, and Vindhyan sandstones, yet every presumption is in favor of that conclusion.

There is much, for instance, to suggest that the schists were disturbed and denuded before the deposition of the Sub-Kymore rocks, and it is certain they were so before that of the Vindhyan sandstones, and remembering the great depth below the surface at which it is presumable that granite is consolidated, the unaltered condition of the rocks of

* The Gogra is a tributary of the Tawa.

† These names will be found explained hereafter.

both these groups, and especially of the latter, renders it difficult to conceive how the immediately subjacent beds of the Schists could have been within the reach and influence of granite intrusion subsequently to their deposition without the effect having extended to them. As however only a small portion of the Vindhyan and Sub-Kymore area has as yet been examined, we may fairly expect that any doubt which for the present remains will be hereafter removed.

Although we may be thus not quite certain whether the granite may not possibly be subsequent to the deposition of the Vindhyan sandstone, there can be no hesitation as to the relative age of the Talcheer group which comes next in ascending order. Its lowest beds contain many fragments of several varieties of the granite rocks, and the source of these can in many instances be traced to masses, the remains of which are still seen in places. Moreover these lowest beds of the Talcheer series not unfrequently rest on denuded surfaces of the granite itself (see below Fig. 7).

To resume then, we find that the granite (all belonging to one geological period) is certainly subsequent to the schists, that it is probably anterior to the deposition of the Sub-Kymore rocks, and almost certainly anterior to that of the Vindhyan sandstone, and finally that there can be no question as to its being older than the lowest Talcheer rocks.

In each of the localities above described, as illustrative of the fact of the disturbance of the schists by granite, it happens that many trap-dykes are also found: these cut through both schists and granite veins, in all directions, sometimes running along the side of the latter, or parallel to them, sometimes passing across them and traversing the schist beds also, sometimes parallel to the bedding lines; and, where these are obliterated, parallel to the planes of lamination, and often obliquely or even at right angles to these.*

* By lamination-planes we understand simply more minute bedding, often among these schists scarcely distinguishable from subsequently induced foliation, but really due to original deposition. It is a phenomenon almost always more or less distinctly traceable in every sedimentary rock, even in the most homogeneous sandstone.

Alteration of rock by Trap dykes

These trap dykes have visibly exercised considerable influence on the texture and structure of the rocks they traverse, palpably altering them at and near the planes of contact. This subsequent alteration by the contact of trap rocks has necessarily rendered it difficult to assign the exact amount of change which is due to the previous contact with the granite rocks, although there is no possibility of doubting after careful examination of the phenomena, that to this earlier contact with molten matter a large proportion of this alteration is due.

Metamorphism of the schists.

This attempt to establish a connection of cause and effect between the granite intrusion and the alteration of the schist rocks in these localities considered in detail naturally suggests the wider question of the relation of these rocks over the whole area occupied by both jointly: and although we have no theory, or even hypothesis, to offer on the subject of metamorphic action generally, and least of all would wish to support that theory which would attribute the present state of the mineralization of the vast thickness of crystalline schists of the Nerbudda Valley, to the presence among them of granitic rocks, still it is nevertheless interesting to trace such relations between these rocks as may now be observable at the surface. In attempting this it will be convenient to examine these relations first as chemical or mineralogical, then as mechanical.

Relations of granite and schist rocks; mineral.

When speaking of the boundaries of the granite masses it was stated that, as a rule, they are very indistinct, the bedded and the igneous rocks passing into each other by insensible gradations—the cases of distinct granite dykes above described being exceptional; indeed although those cases are in finely exposed sections, and quite satisfactory in themselves, the granite being typically the granite of the country, and the schist equally clearly belonging to the great metamorphic series, still they are isolated facts, and similar instances have been but seldom observed elsewhere.

This passage of the granite into the schist rocks, through a more perfectly gneissose variety of the latter, which generally forms a transition band obscuring the junction of the two, would seem to suggest that the causes which produced the highly crystalline condition of the schists generally are unconnected with the granite for the transition band is narrow, nor is there observable on the great scale, any change in the mineral condition of the schists, in the neighbourhood of the granite masses, or presumably referable to them. If the altering action of the granite was, as it seems to have been, confined to the narrow limits of this transition band, it is natural to seek elsewhere for an explanation of the grand phenomena of the general metamorphism of the schist series.

Relations of the granite and schists: mechanical.

If we proceed to consider this same question of the relation existing between granite and the schists from the mechanical point of view, we find the conclusion above suggested, namely, the independence of the schist series of influence due to the granite, confirmed.

The stratigraphic condition of the schists, the dip and strike, &c. of their beds has never, on the large scale been seen to be affected by the presence of the patches of granite. It is true that in detail, as we have shewn above, granite dykes have occasionally broken through the beds of the schists, but these cases are local, and trifling, when the very great mechanical disturbance of the whole series is considered, and it is certain that on the great scale, the general dip and strike of the country hold their direction apparently quite independently of the granite protrusions. Just as, lithologically considered, the schists are quite as crystalline, and as highly metamorphic in aspect away from the granite as near to it, so, mechanically considered, their beds are as highly inclined, and as much contorted, at a distance from the granite, as within a few feet of its boundary.

There is, however, one fact bearing on this question which to some extent would seem to establish a connection between the granite and

the metamorphism of the schists: not as a cause, but as an index of the causes to which that metamorphism is due, whatever those causes may be conceived to be,—for it is certain that metamorphism on the great scale ends with that series which can be proved to be anterior to the granite, and among whose beds the granite has been intruded, while that group next above the schists, (the Sub-Kymore) and which has not been found to be affected by the granite, is not metamorphic.

§ 3. *Metamorphic Series.*

The metamorphic rocks of this district form a very widely spread and very interesting group. Although their limits are laid down on our map they have themselves been but cursorily examined, and the following remarks must be considered more as preliminary and suggestive, than as making any approach to exhausting the subject.

Surface area considerable.

The absolute superficial extent of these crystalloid rocks is much greater than would at first appear from an inspection of our map: they underlie all the recent deposits of the valley, and frequently show here and there through them, both near the foot of the hills, along the north and south side of the valley, and also where the river and its tributaries have cut their channels through the layer of clays, of sands, gravel, &c., and exposed the rock below. Many such localities are marked on the map but many more are too small to be indicated, which still in the aggregate represent a very considerable area, and which from the scattered manner in which they occur show the observer more of the general characters of the rocks than he could probably learn from any equal area continuously exposed.

But besides occupying a great superfical area both in the Nerbudda valley itself, and in that part of the country stretching north east from Jubbulpur to the Rewah country, these rocks again appear in that part

of the Betul and Chindwarra districts which is included in the south of our map, again near Mandla, and again in the Johilla and Mahanuddi vallies far to the east.

Thickness, great.

They must moreover attain a great thickness, although it is difficult to arrive at any very definite or satisfactory conclusions on this point. The beds almost invariably dip at very high angles, after appearing vertical, and their outcrop may be crossed for miles continuously at right angles to the strike: but

Recurring beds.

when the section across them can be clearly seen, beds of a certain texture or composition are found to recur at certain intervals, suggesting that great anticlinal and synclinal folds of the whole series have caused these recognizable beds to be thus repeated again and again at the surface.

Difficulty of identification.

It is clear that to render this kind of evidence conclusive the identification of these recognizable beds must be very close and complete if it be our aim to establish the fact that the different outcrops do certainly belong to the same, and not to merely similar, beds.

Besides which, the amount and direction of the dip at one out-crop, together with accurate measurement of the distance between this and the supposed second recurrence at the surface of the same bed must be carefully determined, as a preliminary to estimating the thickness of the repeated series: all which could only be effected by more detailed examination than has been given and could only be recorded on a map far more accurate than any at the disposal of the geological survey, or than any which the Surveyors could, under the circumstances, construct.

Probably identical.

We sometimes, however, find a section which so strongly suggests the probability of this repetition of the beds, as almost to prove it to be a fact, although the evidence cannot be said to amount to a complete and satisfactory demonstration.

Loreta section.

The rocks exposed on the banks of the Sher Nuddi between the villages of Berkera and Sehora furnish an example of such a section. It is difficult to escape the conviction that here the upper portion of a great anticlinal bend has been removed by denudation. Ascending the stream from Loreta village we find the schist-limestone succeeded by hornblendic and other gneissose rocks, above which again the limestone re-appears and is seen faulted against the upper Damuda beds at Sehora: little can fairly be argued from the dip of the rocks in this section, the beds are nearly vertical all along, and when perceptibly inclined, do not long continue constant to any one direction, still no one could walk over the rocks exposed without being impressed with the conviction that the crystalline limestone seen faulted against the conglomerate under Sehora Village must be a continuation of the lithologically similar limestone bed seen lower down the stream— See section No. IV, pl. II.

Magaruth Section.

Another pretty clear instance of the probable repetition of a long series of recognizable beds occurs in the north east portion of our map.

In passing from Bursa village in the Mahanuddi valley, to Piprod on the great Deccan road (see map) the strike of the metamorphic rocks is crossed nearly at right angles.

The low hills among which the road lies, expose the rocks almost continuously, crystalline limestone is frequently seen at the surface, and the observer cannot fail to be struck by the regularity of the intervals at which its outcrops recur; near the villages of Magaruth and Dongurgaon a long series of beds of the schists, besides these remarkable limestones, may be very clearly traced, and are seen to be very exactly repeated, some of the best marked beds of the *set* following each other in regular order, and recurring in the same order very exactly.

The evidence furnished by such cases as these does not, as above stated, amount to proof, though it may be accepted as a sufficiently near

approach to demonstration; as far at least as the fact that beds are repeated again and again at the surface, and thus exposed by the removal of the upper portion of anticlinal bends, by denudation. In order, however, that such evidence should be used to furnish measurements of thickness, or even materials for a fair estimate of thickness, it would be necessary carefully to record on an accurate map very carefully measured sections, especially where the dip is so high that its deviation from the vertical is often very difficult to observe, and thus little more can now be stated than that after we have made allowance for flexures, there is still ample evidence of very great thickness left. And this must have amounted to many thousand feet: taking only the typical schists of the Nerbudda valley itself, and excluding the sub-Kymores above and all the more gneissose schists of the Betul and Chindwarra country: rocks which belong to the same series and which may be themselves of enormous thickness.

Disturbance great.

Again, we find in these recurring beds evidence of the action of those vast mechanical forces which have thus contorted and disturbed the schists. The kind of evidence on this subject which is afforded by a flat country is never so striking, as when the contorted beds can be seen on the face of escarpments, or the steep sides of high hills, and the lines of flexure traced by the eye, but it is not the less reliable on this account—indeed if the recurring beds be complete and satisfactorily identified, then the flat ground not only proves the existence of flexures on a great scale, but also the removal by denudation of vast masses of rock.

Hinhotia Hill.

It was stated, when describing the granite that no direct connection could be traced between the presence of that rock and the disturbances of the schists; a case illustrating this occurs near Hinhotia hill (see map.) A considerable patch of granite is here found, all round it the schists seem nearly vertical; on the north side of the hill however a constant though slight deviation

from the vertical was observed, forming a dip of about 70° to 80° to the north. Now on examination it appeared that this dip was constant all round the granite mass and noticeably on the south of it.

Prevalence of gneissose character coincides with prevalence of granite.

Again, with reference to the mineral alteration of the schists, a similar independence of the granite vicinity has been already stated to exist, notwithstanding which, it is certain that, in the strip of the crystalline rocks included in the south portion of our map, much more granite is seen than elsewhere among these rocks, and that at the same time the whole series, as there found, is much more gneissose in general character, more highly crystalline, and more thoroughly metamorphosed in aspect.

Lithology of the schists.

Considered lithologically, the schists present many varieties, but even a cursory description of these would be tedious. They are however capable of being roughly grouped under a few classes, and it may be convenient to mention, and briefly describe the principal of these. We shall then speak of—

the Calcareous group,
the Argillaceous group,
and the Arenaceous and Siliceous group,

premising that the classification is very arbitrary and quite irrespective of relative age.

The calcareous schists.

That sub-division of the metamorphic rocks of the Nerbudda district which is characterized by the presence of carbonate of lime is undoubtedly the most prominent and remarkable portion of the series, and if the whole of the beds so characterized be considered, the aggregate thickness must be very great in some places: but among these calcareous schists there occurs an endless variety of gradations, the typical form of the group being the saccharine limestones, which may be considered as shaded off into sometimes the arenaceous, and sometimes the argillaceous schists. The saccharine limestone shows, save only in a few of its massive beds, a more or less

distinctly observable laminated structure: the lines of lamination are sometimes marked by variations of color and texture, evidently due to the presence of new ingredients, and the shading off above spoken of is effected by a gradual increase in the frequency of the recurrence of such indications, and by the intermixture of these argillaceous and arenaceous partings becoming a more and more prominent ingredient in the mass, until from being impurities in a calcareous schist, they come to constitute the rock an argillaceous, or siliceous schist, with layers, bands, and veins of carbonate of lime scattered through it.

Fig. 2. View of the "Marble Rocks" near Jubbulpur, looking up the River, showing the deep gorge of the channel near Bhera ghât

The places where these calcareous schists occur are indicated on our map by irregular lines of blue color drawn along the strike of the country.

About nine miles from Jubbulpur on the south-west, a considerable extent of tolerably pure and beautifully saccharine white limestone is seen; the river cuts a deep channel through the mass of this rock, exposing sheer vertical surfaces of the white limestone, in places 120 feet high: it is scarcely possible to exaggerate the picturesque effect of the varied outline and color of the whole. The locality is well known as the "Marble Rocks" (Figs. 2 and 3). The beauty of the scenery attracts many visitors, and the sacred buildings in the neighbourhood many more.

Fig. 3. Gorge of the Nerbudda at the "Marble Rocks" showing the bedding of the limestone.

Argillaceous schists.

As a prominent feature in the geology of the district the argillaceous rocks are totally subordinate to the calcareous sub-division of the schist series: still they

attain a very considerable thickness in the aggregate, and occupy large areas at the surface.

The boundaries of this sub-division cannot be laid down with precision, any more than those of the calcareous group, into which it merges on the one hand, while on the other it gradually passes into the arenaceous schists; a fact which must of course be borne in mind when the thickness of the beds or the area exposed is spoken of. These argillaceous schists are chiefly micaceous as a whole, the garnetiferous and the andalusite-schists being the most characteristic features of the series.

Arenaceous schists.

In the group which is characterised as arenaceous, and which we mean to include all the schists not referable to either of the former sections, a somewhat heterogeneous set of beds are collected together under one head. All are however fairly described as siliceous in contradistinction to the argillaceous and calcareous sets. We find a very great development of true schistose quartzite, in many parts of the area of the crystalline rocks. This rock is often very massive in spite of its laminated structure, but generally divides into flags more or less regular and is in several places quarried for roofing as well as flooring. The whole set of hornblende schists and rock is also included in this section. Many varieties exist, often characterised by the presence of schorl, and in a few instances by actinolite. Besides these, which are characteristic of beds as such, other minerals, (Tremolite for instance) occur as accidental ingredients throughout whole sections. Besides these, runs of talcose schists and

Steatite.

of tolerably pure steatite, occur among the impure calcareous portion of the series.

True slaty cleavage is of rare occurrence and ill developed.

Much jointing occurs, and has in many cases been observed with care: the number of these observations is however insufficient to warrant any satisfactory conclusions as to the prevalent systems under which the facts might be arranged. Considerable complication exists, the

system of joints which in one place seems to be most prominent, becomes subordinate or quite effaced in another, and many more observations will be necessary before any thing really satisfactory can be stated on this subject.

(a) Sub-Kymore Group.

In 1854 while making a hasty examination of part of the Rewah district, and passing from the Singrowli coal field on the south of Sone river, towards the north, Mr. H. B. Medlicott found a series of beds of considefable thickness intervening regularly between the sandstones of the Rewah plateau and the ordinary crystalline metamorphic rocks.

These beds, underlying the sandstones of the Kymore range are lithologically strongly contrasted with them, as also with the metamorphic rocks to the south: these consist of clay slate and schist or shale, more or less indurated and even sub-crystalline in places, interstratified with thin-bedded fine grained flag stones, sandstone, and laminated quartzite: to this group from its position under the Kymore range, the name "Sub-Kymore" was given.

Found N. E. of Jubbulpur.

Now in the north eastern portion of our map just such a series is found, and situated, as above described, between the metamorphic rocks and the Vindhyan sandstones. To the north-east of Jubbulpur the Mahadeva beds* overlaid by trap, are faulted against the more gneissose schists, and against the granite there associated with these rocks, (see map). If a line be drawn from that boundary in a north-west direction, up to the boundary of the Vindhyan rocks, it will, after traversing the schists above mentioned, cross a considerable area occupied by rocks similar to those to which the name Sub-Kymore has been given. No section has been found which shows the junction between the

Boundaries indistinct.

* Name will be subsequently explained.

true metamorphic rocks and these "Sub-Kymore" beds, nor can their respective limits be accurately laid down here, still there is a very strong presumption in favor of the belief that the latter rest on the former. All along the Nerbudda valley from Jubbulpur west to Pullassi, nothing more of these so called Sub-Kymore rocks is seen. The Vindhyans abut against the true metamorphic rocks, and if the Sub-Kymore series really forms part of a geological sequence, constant between the former and the latter, then the boundary fault must have dropped them out of sight, and have resulted in what now resembles an over-lap of the Vindhyans, stretching in this place, beyond the boundaries of the Sub-Kymore rocks, and abutting against the metamorphic rocks beyond.

These exist as a subdivision.

But again about 200 miles to the west, down the Nerbudda Valley, similar rocks re-appear in the same position intermediate between the Vindhyan and the Metamorphic rocks, in which they were found north-east of Jubbulpur, and originally in Singrowlie.

Found again to the S. W.

Below Hosungabad, and near where a stream called the Tawa* flows from the south into the Nerbudda, the little village of Pullassi stands on the left bank of the latter, and close to it a remarkable section is exposed (see Fig. 18 below). The sandstone beds of the Vindhyan escarpment are seen in their usual position, but a little more disturbed than usual. Within a few yards to the south of them a bed of fine sandstone stands, vertically bedded, and with a strike parallel to the scarp. This vertical bed will hereafter be shown to be a constant feature along the south boundary of the Vindhyans. Elsewhere along that boundary line the metamorphic rocks are invariably found immediately to the south of it, whereas here there is a considerable interval which is occupied by a

Pullassi section.

* Not to be confounded with a much more important stream of the same name confluent with the Nerbudda above Hosungabad.

Lithological characters of the Sub-Kymore.

well exposed series of red shales and schists, with fine quartzite in thin flag beds, often very ferruginous. Although the earthy or (if arenaceous) fine grained character of the group is almost universal yet bands of pebbly layers occur, the pebbles being of jasper, and white quartz principally. Throughout the whole series, as here seen, a very remarkably developed "rippling" of the flag beds is observable.

The group here attains a considerable thickness and is in many ways strongly contrasted with the schists below. In separating it, however, from these on the one hand, and from the Vindhyans on the other, it must be borne in mind that we as yet possess very incomplete data for a final classification. There is much to suggest, and it may ultimately turn out, that the Sub-Kymore group is only a less altered portion of this schist series, into which it passes. On the other hand, several considerations seem to imply a connection between the Sub-Kymore and the Vindhyan groups, and some of these probabilities will be discussed, when we come to describe the rocks of the latter formation.

Thickness considerable.

The separation of the Sub-Kymore provisional.

May be part of the schists.

or of the Vindhyans.

In any case however, and whether the group of which we have been speaking be ultimately shown to be an integral portion of either of the great groups mentioned (*i. e.* of the Vindhyans, or of the metamorphic series), this classification must hold good to a great extent: the "Sub-Kymore" must remain distinct (if only as a sub-division) from both of its neighbours, in lithology, and general aspect, and certainly lies intermediate between the two in geological position.

Justification of present classification.

If part of the Vindhyan sandstone, then its lowest member; if connected with the true schists, then the highest sub-division of that great series.

§ 4. *The Vindhyan Series.*

The remarkable group of rocks which we include under the name Vindhyan does not strictly belong to the subject of this report; it will be found more fully treated of in a preceding part of this volume. In as much, however, as the area described in that paper, is distinct from that which forms the subject of this, and as our remarks will be confined to localities not described, and to questions not discussed elsewhere, it may be desirable to give briefly some of the results of our observations.

Area.

The rocks of the Vindhyan series cover an immense area in Central India (see map Pl. III.) The great table land of Bundelkund and Malwah is mainly formed of them, and their southern boundary, conterminous as it is with that of the table land itself, is marked, as has been stated, by one of the finest physical features imaginable: the vast plateau terminates on the south in a line of escarpment which, stretching from east to west (or more correctly E. 15° N.). forms the north side of the Nerbudda valley, and farther on towards the east holds a similar position in that of the Sone river. Across the high ground of the Jubbulpur district (lying between the valleys of the Nerbudda and the Sone) the prolongation of the line of the Vindhyan boundary, although still clearly indicated in the form of the ground, is very much less prominently and distinctly marked.

Vindhyan boundaries, escarpment.

Escarpment locally absent.

We shall hereafter have occasion to enter fully on the question of the stratigraphy of the formation; so that it will be sufficient here to note, that a slight undulating dip is the rule, so slight as to leave most commonly an impression of general horizontality, in spite of great disturbances which have locally affected the rocks along their south boundary.

The prevalence of regularly bedded fine grained grits with a char-

acteristic red color is the most striking lithological feature of the Vindhyan group : and speaking of the formation generally, its most marked characteristic certainly is the persistency of this lithological aspect over great areas. This sameness of texture is strongly in contrast with the prevailing character of all those more recent sandstone formations to the south, to be hereafter described.

Lithology.

This general constancy in lithological character does not, of course, imply the entire absence of varieties among the beds of the series: instead of clear quartz grits slightly earthy sandstones are found, and in many places ferruginous clay has been so largely accumulated as to form a considerable ingredient in the mass.

Variety.

This earthy matter most commonly occurs at the partings of the arenaceous beds, and sometimes exists as irregular aggregations through the mass of the beds themselves: less commonly the argillaceous and sandy ingredients have been mixed together, producing an earthy, or a shaley sandstone.

Earthy partings.

In many places the sandstone is *mottled*, and spotted, at the surface, from the decomposition of grains of magnetic iron, which is often abundantly scattered through the rock, and may on a fresh fracture, generally be detected in its undecomposed condition.

Mottled Sandstone.

Mica is not a common ingredient of the Vindhyan sandstones, yet occasionally this mineral is present in quantities sufficient to constitute the rock a micaceous flag, and it seems generally to cause, or accompany, a laminated, and fissile structure.

Fissile Sandstone.

Ripple marking may be considered as a phenomenon characteristic of the Vindhyan series; almost totally absent in all the other groups of Sandstone of Central India it is almost every where, throughout them,

found preserved in the most extraordinary perfection. It would be useless to give a list of localities under such circumstances, but Sirbo hill (an outlying hill on the Rewah plateau) may be mentioned as a place where throughout a great thickness of sandstone beds, rippling is beautifully preserved: all kinds of variety of form may here be seen; short deep waves, long shallow ones, the mammillated surface resulting from the meeting of two currents, or from the partial effacing of one set of little waves by the subsequent formation over them of a new set with a slightly different direction. The "Great Deccan" Road between Rewah and Myhér runs close to the south of Sirbo hill.

Rippling.

While speaking of the varieties of the Vindhyan Sandstone it must be noted that even the fine grained character, although well nigh universal, has its exceptions. Some few thick bedded coarse sandstones occur; such beds may be seen just above Kuttra Ghât, and again near Myhér; far to the east near the city of Bhopal, and in the bank of the Nerbudda at a village called Menda, near Hindia. Pebbly and conglomeratic layers are exposed on the east side of Bhopal lake, as well as the coarse sandstone; and pebble bands also occur at the locality mentioned near Myhér.

Coarse grained Sandstone.

The section exposed at Kuttra Ghât as well as the parallel one at Bilohi ghât, shows that the sandstone of the Table land is there supported by a considerable thickness (not less than 400 feet) of beds very unlike the sandstones themselves, being shales and micaceous flags. Captain Franklin speaks of these beds as "primary schists," an error corrected shortly after by Jacquemont (see introductory chapter) and of the sandstone above as "New Red." Far from there being any unconformity between the rocks of the bottom, and those of the top of the Ghât, the character of their junction is transitional, the shales pass up into earthy flags, and frequent alternations of the earthy and sandy members of the series occur.

Lower beds of Kuttra Ghât.

A Section perfectly analogous though not identical with this, may be seen between Rewah and Myhér, in Sirbo Hill before mentioned; though probably belonging to a different part of the Vindhyan series, this Sirbo Hill section looks like a repetition of the Kuttra Ghât one.

Lower beds of Sirbo Hill.

In the bank of the Sonar, south of Sagur, a considerable thickness of green shale and earthy flagstones is found, underlying the tabular masses of the Vindhyan Sandstone.

Lower beds of Sonar section.

Again in the Nerbudda valley itself, similar shale beds appear more than once, where the Vindhyan sandstones have been denuded in those bay like curves, which stretch back north of the straight line of their general faulted boundary: they may be well seen near Silwani, and Sirmow, and thence to the east and south down to near Birman Ghât on the Nerbudda. Thus then it appears that the sandstones of the Vindhyan series are associated with a considerable thickness of shales which are seen to accompany them in several parts of their area, and at points widely separated from each other. At Bilohi and Kuttra (above mentioned) this shale group is found to be mixed with a considerable thickness of siliceous bands; thin layers of quartzite, little vein-like beds of quartz, and earthy flags, go in the aggregate to make up a large part of the mass. At Sirbo, on the contrary, the whole is argillaceous, and the pure earthy green shale is seldom interrupted by siliceous layers; but in the Sonar, south of Sagur, and still further south the mixed character re-appears.

Same section repeated near Silwani & Sirmow.

Resumé.

When speaking of the group of rocks called provisionally Sub-Kymore, we have stated that in the section near the village of Pullassi, (page 139, ante,) a considerable thickness of indurated shales, and thin-bedded quartzite, with micaceous layers, and much finely marked rippling, is found just below the undoubted

Analogies of these beds with the Sub-Kymore.

typical Vindhyan Sandstone—also that in the north part of the Jubbulpur district a series of indurated slaty shales occupy a large area between the same Vindhyan rocks on the one side, and the crystalline schists and metamorphic rocks on the other. Now a comparison of these observations seems, we think, to suggest, that the latter may be only the more altered representatives of the former, namely the more arenaceous Pulicassi beds, of those of a similar character at Kuttra, and Bilohi; and again the slaty argillaceous beds of Punagur, the representatives of the shales of Sirbo Hill. While it is convenient here to maintain, provisionally, the separation of these Sub-Kymore from the Vindhyan rocks above, and from the more crystalline rocks below, yet the question of their true relations must be in reality reserved until more is known of their habits, and especially regarding their junction with the metamorphic series on which they rest.

Absence of fossils.

In the Vindhyan series no fossil has as yet been found. No trace of organized existence has ever rewarded much laborious search among the beds of this group. Some day, we have no doubt, fossils will be discovered, but meanwhile it is vain to speculate on the possible age of this formation. The far more simple question of the relation of the Vindhyan to the newer rocks next above them in the general section is but obscurely made out, at least stratigraphically considered: no section showing superposition has been found within the area now described, some fragments of a rock attributed to the Vindhyan Sandstone are found in the lowest conglomerate of the Talcheer and Damudas of the Nerbudda valley; little more however of tangible direct evidence can be offered.

Indirect evidence.

The indirect evidence bearing on the question, abundantly makes up for this deficiency, and no geologist, after examining the country, could fail to perceive that the Vindhyans are geologically distinct from all those rocks to the south which are next to be described. The circumstance that almost all pre-

vious observers had confined their labors to one or other of the rock areas, without comparing these with each other, accounts for the fact that the separation of these rocks, as a distinct group, had not been made previously to the visit of the Geological Survey in 1855. This separation was subsequently announced to the Asiatic Society, Calcutta, by Professor Oldham, after his visit to Central India, in 1856.

§ 5. (*a*) *Talcheer Group.*

(*b*) *Lower Damuda Group.*

General area of the newer sandstone.

If we take together the sub-divisions § 5, § 6, and § 7 of our list, it will be seen from the map that rocks belonging to these groups, form the ranges which bound the Nerbudda valley on the south, as the Vindhyans do that which bounds it on the north.

Nowhere have the Vindhyans been seen in contact with any of these rocks, and between the boundaries which respectively limit the two groups a long narrow strip of country lies, which may be considered as occupied by the crystalline rocks, these being however, for the most part, covered by the more recent ossiferous sands, and gravels, and surface clays.

N. boundaries.

The area occupied by the rocks of our groups, § 5, 6 and 7, lower and upper Damuda and Mahadeva collectively, is limited on the north by a very straight line running along the base of the ridge which bounds the Nerbudda valley on the south. Looking at the map, pl. II, and commencing at Lokurtullye, at the extreme west of it, this line will be seen to hold a very rectilinear direction, throughout the whole of its length, to the Rewah country on the east, and it is believed to keep the same course down the south side of the Sone valley. Bounded by this line on the north, the rocks above referred to may be seen to occupy a considerable area to the south of it. They are covered by the trap to the south, and west of Lokurtullye.

They are known to occur again at the surface to the westward in the Kalibete Hills, and have been described near Ellichpur, but as far as the area included in our map is concerned, the trap bounds them on the west.

W. boundary.

The sandstone area, of which we are now speaking, is bounded on the south by a line nearly parallel to its north boundary. This south boundary line stretches for 70 or 80 miles also in a very rectilinear direction, from about the meridian of Betul to that of Chindwarra station, lying a few miles to the north of both these places. Thus bounded on the north, west, and south respectively, this sandstone area is limited on the east (as on the west) by the overlying trap. Rocks of the same formation have been described as occupying large areas in the Nagpur country, but these are beyond the limits included within our map.

S. boundary.

E. boundary.

Passing to the eastward from the eastern limit above indicated, that is roughly, from the meridian of Nursingpur and Chindwarra stations, only a narrow strip of ground will be found occupied by rocks of the Damuda and Mahadeva groups. They are very continuous along their northern boundary, but no where are they found to extend far from it to the south, until we come to the valleys of the Mahanuddi and Johilla, where they once more spread over a wide extent of surface. All along, their limit in the southern direction is marked by the overlying trap of the Seoni, Mundlah, and farther on, of the Sohagpur districts. We shall now proceed to describe these formations in detail, and in ascending order.

Extension of the same rocks to the east.

These rocks are exposed in several places at the base of the range of Hills which bounds the Nerbudda Valley on the south, and principally at the entrance of gorges communicating with the valleys of the interior of these ranges. The area occupied by them is only seen in detached, and often small patches, most of these being in places where the rocks of newer formations have

Area of the Talcheer.

evidently been removed by denudation from above them, and they always occupy the lowest ground among the hills formed of these newer rocks.

General lithological description.

In describing this series lithologically we shall make use of the following sub-divisions, which are based upon the most prominent and important characters, found best developed, in the majority of the sections examined. They will be found useful for reference, in subsequent and more detailed descriptions, and show at a glance the principal features of the group.

(a) Obscurely bedded, or unbedded masses of green mud; occasionally finely laminated, and frequently showing besides a characteristic and very complicated jointing.

(b) The green mud of (*a*) becomes sandy, or even gravelly. In proportion as this character obtains, the shaly lamination dies out, and the rock seems also to be then unaffected by the peculiar jointing. The rocks included in this sub-division (*b*) tend to pass into an earthy sandstone with distinct bedded structure.

(c) Sub-divisions (*a*), and (*b*) pass into each other and either indifferently underlies the other: embedded either in the fine silt of (*a*), or in the more sandy mass of (*b*), there are frequently found in great numbers rounded blocks of gneiss and granite, sometimes mere pebbles, but often attaining great size. A maximum diameter of 5 feet 8 inches has been measured, and 4 feet 6 inches is a common size. This sub-division has been called the "*Boulder Bed.*" See Cuttack Report.

(d) Green, grey, and blue shales with and without carbonaceous markings.

(e) Flags, green and grey, often very carbonaceous.

(f) Coarse *grey*, brown, and red felspathic sandstones.

The sub-divisions *a*, *b*, and *c* may be considered as the representatives of the Talcheer group; *d*, *e*, and *f* of the lower Damuda.

In the Geological Survey Report on the Cuttack district* there has been described a series of deposits having near its base a *Boulder bed*, and green muds, and on which the beds of the Damuda group unconformably rest. In Central India, there is at the base of the series a group of deposits lithologically, and in general habit, strikingly like these *Talcheer* beds. They have therefore been separated from the lower Damuda Rocks above on the strength of these lithological resemblances, although no similar unconformity seems here to divide them. On the contrary, it has been found impossible to draw any line between the Boulder bed, and other beds which contain the remains of Glossopteris, Vertebraria, Phyllotheca, and plants common in the Damuda formation and not known to occur in the Talcheer beds.

Unconformity of Talcheer group, obscure in Central India.

A more extended knowledge of these formations may enable us to establish a physical line of demarcation between the Talcheer and the Damuda Rocks of Central India, but for the present it will be sufficient to point out its possible existence, treating meanwhile the Talcheer and Lower Damuda groups as one.

In all the best sections which we have and wherever there is reason to suppose that the bottom of the series is exposed, the rocks belonging to our sub-divisions, *a*, *b*, and *c* are found to underlie all the other beds. They are invariably, even when feebly represented, found at the base of the series; nor have any of the beds included under *d*, *e*, and *f*, been ever seen to rest on the schists or granite.

Never overlie the Lower Damuda.

Commencing from the west of the larger map, some rocks of this section may be seen south of Lokurtullye. The Morun River exposes some beds of the Lower Damuda series; shales, flags and sandstones, and a bed of poor coal,† come to the

Morun River beds

* Memo. Geol. Surv. of India, Vol. I.

† With respect to the coal seen here we may remark that it is at its out-crop about 3 feet thick but very much impregnated with pyrites; a strong efflorescence of sulphur and of Alum covers its exposed surface, as well as that of some of the accompanying shales.

surface (*d*, *e*, and *f*, of our list, page 148.) The beds have been considerably disturbed, and the massive thick sandstones of the Mahadeva group (see below) rest unconformably on them.

Area very small here.

The Damuda beds are found only at the bottom of the Morun glen, and only a very small patch of them can be seen, both sides of the glen are formed of Mahadeva sandstone (as stated above) and on the west these are almost immediately covered up by Trap.

Tawa Valley.

Proceeding hence towards the East, the Damuda and Talcheer beds will be seen to occupy a large area in the Valley of the Tawa. (See map.)

The Tawa is a considerable stream confluent with the Nerbudda a little above Hosungabad, and which issues from the hills on the south side of the valley through a gorge, at the entrance of which the old fort of Bagra stands.

It drains a very large area within the range to the south, its numerous tributaries reach many miles to the east and west among the hills, and itself flows across a wide plain surrounded almost on all sides by the high ground. All the low ground of this plain, and of many of the glens which open into it, is occupied by the rocks under consideration, and many fine sections of them are exposed.

Rocks exposed.

Talcheer.

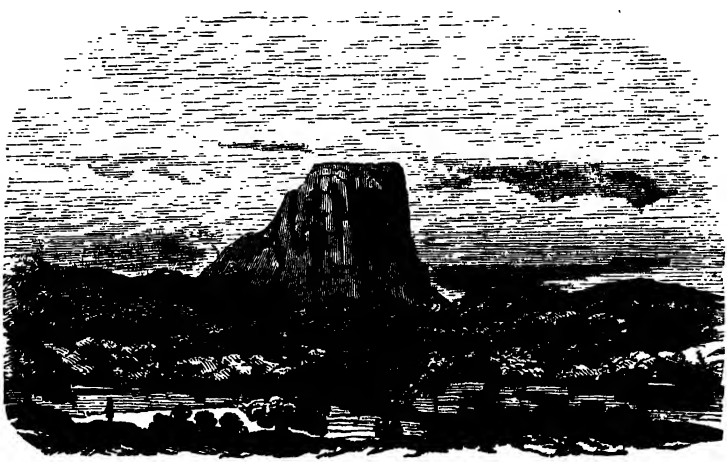
The green muds and Boulder-bed (*a*, *b*, *c*,) are occasionally met with in almost every part of this area, but they are far more largely developed towards the south of it and it is there that they may be best studied.

Such impurities, if equally abundant throughout, would render the mineral commercially useless; a circumstance the more to be regretted as no coal is known to exist to the west of this place, and the position of the out-crop gives it many advantages over Sonadi, which is, next to this, the most westerly coal of the district. From that place a quantity of coal was taken to Bombay some years since under the auspices of Sir R. Hamilton. Situated on the level of the Nerbudda Valley, and many miles to the west of any other known out-crop, this locality will doubtless receive a trial, whenever a demand for the mineral exists within a distance sufficiently short to admit of its being worked to a profit, after cost of transport has been paid.

This lower, or Talcheer portion of the series, is very well seen in the glen of the "upper Tawa," a glen at the head of which the old hill fort of Hurriaghur stands, and through which the Tawa runs in a westerly direction into the wide open valley in which it meets many of its tributaries and swells to a large river. The green muds and Boulder-bed are there very well seen, as indeed they are all along the south of the Tawa drainage, in the valley of the Machna and in that of the Sooki. The accompanying sketch is taken from this latter valley, looking towards Bowerghur hill; the flat and slightly undulating foreground is occupied by the green mud and earthy sandstones, which are, at the base of Bowerghur, faulted against the crystalline rock of which that fine block is formed.

Upper Tawa Valley.

Fig. 4. View of Bowerghur Hill, seen from the valley of the Sooki.



Along this southern drainage of the Tawa these green muds must attain very considerable thickness, but it is very difficult to estimate to what it may amount in a rock so destitute of bedding as the nearly amorphous masses of the Talcheer group generally are. Some approach to arrangement, visible in parts of the deposit, (see description of subdivision *b* above) sometimes

Thickness of green silt.

affords data for roughly computing the thickness, and taking advantage of this it is found that the group is here represented by a minimum of 600 feet, but it is probable that this estimate is very much too low.

South boundary of these Rocks.

The character of this south boundary of this formation is not uniform, the beds being sometimes faulted against those of the schists, and sometimes found resting unconformably on them.

The phenomena of the faulted part of this boundary will be fully discussed hereafter, while the accompanying sketch gives a good example of an unconformable junction.

Fig 5. Section in stream W. end of Rawundeo Hill.

(*a, a,*) Recent clays, sand and shingle deposited on a denuded surface of the Talcheer rocks.

(*b, b,*) Talcheer beds: at the top the soft earthy sandstone, and sandy mud beds are very regularly bedded (*b*, of list of sub-divisions) and dip at a low angle. Below the *Boulder-bed* is seen: it contains here some large blocks; one of these was observed to consist of a fragment of a Trap dyke, with some of the mica schist through which it cut, still adhering. Such a fragment might be broken now from the dykes seen in sites immediately below.

(*c,*) The crystalline gneissose rock much contorted and foliated, here principally micaceous and hornblendic.

(*d,*) Granite—intruded among the schists, in one place the foliation of the schist dips towards the surface of the granite, where in contact.

(*e,*) Trap dykes—one through the granite and one across the foliation planes of the schists.

Description of section.

The Talcheer beds are here deposited on an old irregularly denuded surface of the crystalline rocks, and on their denuded surface again rest the recent clays and gravel of this part of the country.

No section has been found in this part of the district, showing any very considerable thickness of rocks from the bottom upwards, in continued sequence. Elsewhere such a section does exist and will be described when we come to the eastern part of the country; but here, as a rule, the frequent faulting, and numerous trap dykes, so cut up the beds,

Dykes and faults obscure the section.

that a long sequence is never left unbroken. This is apparent in the section which will be now described, for not only is the lowest group (the Talcheer portion of the series) not connected with the upper, but the beds best exposed are both faulted, and traversed by dykes, and thus the true measurements are obscured and rendered uncertain.

Section at Rawundeo.

The Tawa river, as it flows under Rawundeo Hill, exposes a good section of the true lower Damuda rocks. To the south the Boulder bed and green mud are seen, as has been stated, faulted against, and sometimes resting on the schists: here they do not appear.

The path from Salyia village to the old hill fort of Asseerghur (see map) after passing over the east end of Rawundeo Hill crosses the Tawa river a short distance to the north of it.

At the ford we find thick beds of the ordinary felspathic sandstones of the formation (subdivision, *f*, of our list) which have here an irregular rolling dip. These beds soon disappear beneath the surface deposits, and if we descend the stream, are again, at intervals, seen. Not far down a line of fault, marked by a band of brecciated rock, traverses these beds, heading W. 10° N.; below this again a fine trap dyke, seventy feet wide, cuts across them, and heads due north: the sandstones, as well as the obscure bedding permits of identification, seem to be the same beds all

along and continue to be exposed in the river banks with little interruption. A short way below the dyke, the rocks become clearly bedded, and their dip may be observed, the section in *descending* order from thence exposes

——— Rough grey felspathic sandstone with many nodules of pyrites, beds massive, thickness obscure.

——— A flag bed.

3 feet 0 inches Fine blue shale.

3 „ 6 „ Coal, A.

1 „ 3 „ Sandy shale.

4 „ 6 „ Hard sandy shale, and hard flag.

30 „ 0 „ to 40 feet—Coarse grey felspathic sandstone with nodules of pyrites, which look like a repetition of the beds noted at the top of the section; no indication of a fault, by which they might be thus brought to the surface again, is however noticeable.

The dip down to this is somewhat equivocal; but here it seems to be steady, 15° to E. 5°, N.

4 „ 0 „ Coal—A'—includes two bands of blue shale whose aggregate thickness is about nine inches, the coal is pure, light, and bituminous. The four feet given is a minimum thickness; for the bottom of the bed is not seen. On the supposition of the repetition above suggested this coal would be the same bed as the three feet six one noted already and marked A.

10 „ 0 „ Flag beds, not well seen, hard and soft flags, and thin sandstones, thickness somewhat uncertain.

The continuity of the section is here interrupted; rocks soon again appear in descending the stream, and keep on the same general direction of dip. *In descending order*, we have,

7 feet 0 inches Brown and grey felspathic sandstones, dip E. 15°.

1	feet	6	in.	Coal B. Very good quality; the floor of seam not seen, so that this is a minimum thickness.
33	„	0	„	Flags, (c) There is an out-crop of 75 feet horizontal measured across the strike, in the direction of the dip, here E, 35° N.; at the top, the dip is as low as 15°; at the bottom it has increased to 45.° The flags are hard, brown and interstratified with six inch and two feet layers of similar sandstone with carbonaceous partings.
20	„	0	„	Black carbonaceous shales, interstratified with hard micaceous flags.
1	„	0	„	Carbonaceous shale—roof of
2	„	6	„	Coal—D.
2	„	0	„	Dark carbonaceous shales.
1	„	0	„	Hard brown flags.
5	„	0	„	Hard sandy micaceous shales.
5	„	6		Flags, with black shales and a thread of coal.
4	„	0	„	Flags.
4	„	0	„	Fine laminated blue shales.
15	„	0		Alternating flags and grey sandy shales very hard below.
5	„	0	„	Flags and shales with a thread of coal.
5	„	0		A bed of fine grained fissile sandstone.
1	„	0		Black shales.
1	„	0		*Coal.*
6	„	0		Hard, earthy, laminated (or fissile) flags, with a thread of coal.
0	„	0	„	Hard, white fissile sandstone, with carbonaceous markings and partings, thickness obscure.

A fault here crosses the section, but its direction is not clearly ascertainable, the whole mass being confused and broken up irregularly—below this break we have

10 feet	0	in.	to 12 feet hard flags and shales including a band of eight inches of coal, B.
40 „	0	„	flaggy sandstones (*c*), two flag beds, finely rippled in places, indistinct impressions of plant stems uncarbonized, earthy partings, a few bands of hard black micaceous shale. This set of beds has a higher dip at top than below, decreasing from 35° to 15° or 12°, the *direction*, which is constant, is E. 30° N.
2 „	6	„	Coal D.
„ „	10	„	Black carbonaceous shale.
0 „	0	„	Hard micaceous flags—

There is a break in continuity here below.

15 feet	0	in.	Soft grey felspathic sandstone.
10 „	0	„	Soft sandy shale, and grey fissile flags.
3 „	0	„	Coal. With this coal a thin layer of sandy shale is sometimes interstratified dividing it near the floor, but there is three feet of good coal exclusive of this.

Break in continuity of section.

15 feet	0	in.	Grey sandstones.
10 „	0	„	Grey shales.
3 „	0	„	Coal.

being evidently, or most probably, a repetition of the twenty-eight feet seen above the break.

Below this a break occurs again, and beds exactly like those first described, at the ford, again appear; thick but irregular beds of grey and brown felspathic sandstone ; dip obscure, and thickness not ascertainable.

Remarks on the above section.

It appears on looking carefully over this section that, neglecting all *threads* or very thin bands, we have a total thickness of 21 feet 2 inches of coal.

The beds dip at low angles, the out-crops, eight in number, all occur within the distance of a mile, four of them expose beds of from three to

four feet thick, and four beds of from one to two and a half feet thick; and the quality of the coal is good throughout. If however we are correct in the conjecture that in some cases the same bed has been brought twice to the surface by a fault, then the real aggregate thickness of the beds below would be reduced to about 10 feet 8 inches.

We may here remark that the thickness of the upper sandstones, (those which were described at the top of our section, and stated closely to resemble those again found below it in descending the stream) although not capable of being measured, must be very considerable; and the question of the estimation of its amount will be hereafter discussed.

Faults; probable effect.

Reverting to the subject of the faults, which we have above stated may so have shifted the beds as to bring the coal marked A in our section to the surface again, in the position marked A′, it will be found that a vertical shift of 45 or 50 feet will satisfy all the conditions. The dip of 15° may be assumed to be constant, and for beds inclined at so small an angle a displacement equal to the thickness of the beds intervening between the two out-crops of the coal, would be sufficient to account for their present relative position, on the supposition that they are in reality parts of the same layer. Although however, taking into consideration the similarity in lithological character of the two sets of beds noted, it certainly does seem probable that the set found between the two coal seams, is merely a repetition of that seen immediately above the higher of those seams, yet this is not necessarily the case; it is quite possible that no fault exists, and all the beds *may* be distinct, in which case the similarities mentioned are naturally accounted for on the ordinary supposition that conditions such as produced the former, again in the same order of succession, obtained during the accumulation of the latter series.

Again, we find several breaks in continuity occurring below the point

just left ; there is nothing however to suggest that any fault shifts the beds in any of these places, and thus we find, in descending order, about 130 feet, of alternating flags and shales, &c. This includes two seams of coal 1 foot 6 inches and 2 feet 6 inches thick, respectively, and separated by about 56 feet of the flags and shales. At the bottom of these 130 feet, some obscurely bedded sandstones come in, which are estimated roughly at 10 to 20 feet thick, and at the base of these a fault has cut off the rock. Taking this set as terminated here, we find on the south side of the fault, (descending both the stream and the geological section) some flags and shales with 8 inches of coal, below which 45 to 50 feet of flags and shales, and then a 2 feet 6 inch coal seam occur; and we have only to suppose the fault above mentioned to have been a downthrow on the north of 140 to 150 feet when we shall find in the 8 inch and 2 feet 6 inch coal bands respectively the representatives of the 1 foot 6, and 2 feet 6 bands of the upper series. The average dip is, as in the former case, slight, and the amount of vertical displacement may therefore be taken, here also, as equal to the thickness of the intervening beds, as nearly as need be. General lithological similarities certainly suggest the identity of the two sets of beds; and although only 45 to 50 feet of flags and shales are found between the 8 inch and 2 feet 6 inch coal of the lower section, while 54 feet of similar rocks come up between their (supposed) representative above, yet such a discrepancy, as well as the difference of 10 inches in the thickness of the smaller band of coal at its (supposed) two out-crops, is nothing more than an acquaintance with the usual manner of deposition of the formation would lead the observer to expect: here however, as in the former case, nothing more than conjecture can be hazarded.

Probable thickness of coal

The only other point in connection with this Rawundeo section to which attention need be called, is that the set of beds described at the bottom of our measured list, which have also been stated to be repeated by a fault, and are about 28 feet thick (including a 3 feet coal seam)

are, as a whole, unlike the other rocks of the section. They are soft and friable and very felspathic; whereas the others are hard, gritty or earthy; the roof and floor of the coal here are of sandstone, and not as in the other rocks, of carbonaceous shale. In this case also, it must be remembered, that the supposition of the two coal seams being, in reality, parts of a single bed, brought thus twice to the surface by a fault, rests on the close resemblance in the character and order of sequence of these beds supposed to be repeated, and could not be absolutely proved to be the case save by boring.

Machna Section.

As another example of the prevalent characteristics of these Lower Damuda rocks in this district a measured section is appended of the rocks of the Machna river as seen between Shapur and the Tawa. Descending section: dip varying from E. to N. E.*

Thick bedded massive sandstone, (one bed 20 feet thick) a few bands of carbonaceous matter included in this sandstone; it becomes more thin bedded and more earthy in descending.

10	feet	0	in.	More thinly bedded brown sandstone.
1	„	3	„	The same, becomes flaky and with imperfect impressions of vegetable remains.
1	„	6	„	Blackish, grey sandy shale, (clunch.)
0	„	6	„	Flaky shale, blackish.
0	„	6	„	Sandstone with black partings.
1	„	2	„	Whitish felspathic soft grit, fine grained.
0	„	1	„	Black shale, partings of coal in places, in others wanting.
0	„	9	„	Soft grit.
0	„	1	„	Shaly parting.
0	„	5	„	Sandstone with coarse ferruginous nodules.
2	„	6	„	Grit.

* From Mr Oldham's notes.

0	feet	1	in.	Shaly parting, flaky, black.
0	„	3	„	Flaky sandstone.
1	„	3	„	White sandstone.

N. B. The group taken so far varies much along the strike, and a short way to the south many of the above noted alternations are wanting, and the relative position of many changed.—Continuing as before

0	feet	9	in.	Flags, grey and slightly micaceous.
2	„	6	„	Do. more shaly, thinly laminated.
0	„	3	„	Grey clunchy earthy sandstone.
0	„	4	„	Do. flaky, with carbonaceous partings.
0	„	6	„	Light grey micaceous sandstone.
1	„	0	„	Sandy shales, blackish.
0	„	6	„	Grey carbonaceous sandstone, flaky black partings.
0	„	9	„	Sandy shale.
0	„	4	„	Grey carbonaceous sandstone.
2	„	3	„	Blackish shaly sandstone.
2	„	6	„	Sandstone with black carbonaceous partings.
0	„	4	„	Sandstone.
0	„	10	„	Black flaky, sandy shale.
0	„	3	„	Black carbonaceous sandstone.
0	„	6	„	Flaky sandy shale.
2	„	2	„	Black shale, ferruginous, with ill preserved Glossopteris.
2	„	3	„	Coal, very bright and jetty.
1	„	3	„	Black shaly layers, upper part very bituminous, with seams of coal.
0	„	3	„	Sandstone with carbonaceous markings.
0	„	0	„	Alternation of shale and thin bedded sandstone.

A fault with a downthrow to the south is here seen, and farther on a second fault with a southern downthrow is seen; it heads E. and W. and underlies 45° to the S. The amount of displacement is about 3 feet. That

of the first fault cannot be seen, but below the second the coal re-appears, probably the same seam as that measured above. Under it come,

0	ft.	6	in.	Shale.
0	„	2	„	Sandstone.
1	„	0	„	Shaly sandstone.
1	„	?	„	Shales.
5	„	0	„	Sandy flagstones, with shaly partings and carbonaceous markings.
0	„	2	„	Fine shale, finely laminated.
0	„	9	„	Sandstone with carbonaceous markings.
3	„	6	„	Black flaggy shale.
4	„	6	„	Shale, more earthy and finer than the above, coaly or bituminous in parts, with threads of coal; these threads are confined to the upper part, which forms a layer of 5 inches. Sulphur is plentifully thrown out, shewing the existence of much pyrites.
3	„	0	„	Black flaggy shale and flags.
4	„	0	„	Sandstone, irregular on bed surfaces; irregular partings of black shale.
3	„	0	„	Sandstone, fine clean quartzite grits, sharply angular or slightly rounded grains with fragmentary bits of coaly matter through it.
0	„	3		Coal.
0	„	9		Black shales, flaky.
1	„	8		Flaggy black sandy shales.
4	„	0		Sandstone flags, earthy partings; current-markings abundant.

The dip here curves slightly to N. 20° E.

3	ft.	6	in.	Black shale.
3	„	0	„	Flaggy rippled sandstone.
2	„	0	„	Flaggy sandstone.

Thick massive sandstone, *white*, and in all respects like that above described at the top of the section.

From a study of these sections a tolerably correct idea of the litholo-

Remarks on the above sections.

gical characters and of the formation may be gathered, the sections given having been selected as typical. The rocks enumerated are those which are included under the sub-divisions *d*, *e*, and *f* (namely the lower Damuda) of our list.

It is interesting, and indeed very important, to obtain some reliable

Estimated thickness of the lower Damuda.

estimate of the thickness of this portion of the series, for it includes all the really valuable coal of the country, and many of its shales abound in fossil remains. Most of it is sufficiently clearly bedded to afford satisfactory measurement of dip, so that the difficulties met with in estimating the thickness of the Talcheer group no longer exist here; but others unfortunately occur, some attempt to meet which must now be made.

It will have been remarked in looking over the above sections that both

Difficulties, variable character.

the amount and direction of the dip is variable within very short distances, indeed the dip is very rarely so constant as in the sections noted, and is very often inverted several times within far shorter distances. As a rule the beds roll; the curves of the anticlinals and synclinals being sometimes very sharp, this is the first obstacle encountered when an estimate of the thickness is attempted.

The next consists in the numerous faults everywhere found, some-

Number of faults.

times these are so exposed as to shew on which side the downthrow occurs; sometimes even the amount may be fairly estimated if not actually measured; but the commonest case is that in which the existence of the fault is indicated by a line of fault rock (a breccia which will be more fully noticed hereafter) where, from the very nature of the action which has affected the beds at the line of fracture, the identification of any of these, at opposite sides of the break, is generally very unsatisfactory.

In addition to these causes, the trap dykes tend greatly to obscure any measurement of the thickness of the beds. Sub-divisions (*d*) and (*e*) that is the flags and shales of the series occupy very considerable area in the Tawa valley; they are often seen at the surface supported by the green muddy boulder bed, and generally overlaid by the massive sandstones described as (*f*) in our list. And an examination of the whole series, regard being had to all the above sources of error, leads me to estimate the thickness at not less than 700 feet for the flags and shales (*d*) and (*e*). The difficulties of getting at the thickness of the entire group do not, however, end here, for the upper sub-division (*f*) still remains. Coarse thick bedded grey and brown felspathic sandstones form the top of the lower Damuda series, as has been shown in both the sections above given: these and even the beds below them, were disturbed and extensively denuded before the deposition of the Mahadeva sandstones, which here rest unconformably on them. This unconformity is however often very slight, often so slight as to be in short sections quite inappreciable. There exists, moreover, sufficiently strong lithological similarity between the lowest part of the Mahadeva sandstones, and this upper member of the Lower Damuda group thoroughly to obscure the junction between the two.

Trap Dykes.

Thickness of upper division.

This has been denuded.

The observer standing on the gently undulating flags, shales, and sandstone, of the Sonadi coal section, in the valley of the Bora Nuddi (see map) and looking towards Jamgur Hill, which is formed of Mahadeva sandstone, will be able to perceive that the lower rocks (of the valley) are unconformably overlaid by the massive sandstone beds of the hill; but if he proceeds towards the foot of the latter, he will find that these sandstones seem to pass down into those of the low ground, and this so gradually, and imperceptibly, as to render it difficult, or often impossible, to determine the exact position of the line which divides the two.

Upper limit not clear.

This same feature is very strikingly displayed on the south side of the

great Puchmurri Hills, of which the accompanying sketch, (Plate IV), presents a view. The sandstone of the escarpment when looked at, as in this view, from the valley below, presents a character not only different from, but strongly contrasted with, that of the rocks of the low ground (in this place flags and shales of the lower Damuda series), and still the difficulty of determining the position of the line of demarcation between the two formations exists even in the best exposed sections. Few, however, of these are found free from the talus which generally hides all rocks in place along the base of the hill.

It is superfluous to state that in order to measure the thickness of the highest member of the lower Damuda's sub-division (f), its upper limit must be definitely fixed, and thus we are here again reduced to unsatisfactory approximations and estimates which, however cautiously they be made, must remain uncertain and to a great extent conjectural.

Thickness estimated.

There is no positive evidence that this member of the lower Damuda-group is now represented by a thickness of more than 400 or 500 feet. It has, as being found at or near the top of the series, suffered much from denudation, and may once have attained to very much greater dimensions. It is indeed this portion of the series which more especially swells to such wide proportions in the Johilla sections, and it may hereafter appear, that very considerable portions of the sandstone masses of the Gondwarra hill district, which must be for the present included within the Mahadeva boundaries, in reality are outstanding and undenuded portions of the lower Damudas.*

Summing up what has been already stated on the subject of the thickness of the rocks of the Tawa valley district, we have for

The Talcheer group (a_1) (b_1) (c_1)	600	
Lower Damuda ditto (d_1) (e_1)	700	
Ditto ditto ditto (f_1)...	450	
		1,150
A minimum thickness in total, of		1,750 feet.

* As a possible case of this we may mention the massive sandstones of the Kangla pass.

This is only about one-half the minimum thickness of the same series as seen in the Sohagpur country, and, as just stated, the greater portion of the difference between the two must be assigned to the upper sub-division (*f*) of the above list.

Leaving the Tawa valley and proceeding up the Nerbudda valley for about 35 miles (in a *straight* line) the hill district may be again entered through a gorge, at the mouth of which the fortified village of Futtehpur stands (see map). Within and south of the narrow glens which connect it with the Nerbudda valley, lies a wide spread of flat country.

The flat ground is occupied by the Talcheer and Lower Damuda beds, it is drained by the Deinwa river which, passing from here to the west among the hills joins the Tawa just above Bagra. This may be called the Lower Deinwa valley, and if we follow that stream, up its course, it will be found to wind through deep glens, and between high vertical scarps, as it works its way, from south to north, among the eastern and lower spurs of the Puchmurri Hills. Again, to the south of these, its valley becomes once more wide and flat. The stream itself and its tributaries, draining the country under the southern face of the great Mahadeva sandstones of Puchmurri, expose many fine sections of the rocks of the Lower Damuda series, (rocks like the (*d*), (*e*) and (*f*) of our list), and similar to those seen in the Tawa valley. Similar to these in texture and structure we have fossiliferous shales, flags, and seams of impure coal, and like them in habit we find an irregular and sometimes inverted dip, faults, and trap dykes.

Deinwa valley.

The following sections will serve as examples of the general character.

Gorah Section.

Section near Gorah village on a tributary of the Deinwa River ascending.*

Thick massive whitish sandstones—

5 ft. 0 in. Grey clunchy clay,—no partings into laminae, and altogether like a sand bank.

* From Professor Oldham's notes.

2	ft.	0	in	to 2 ft. 6 in. Blackish grey and black shales,—irregular, flaky, but not very fine; abounding in impressions of *Vertebraria, Glossopteris* and *Phyllotheca.*
1	„	0	„	Irregularly deposited grey mud.
6	„	0	„	Massive beds of greyish sandstone with some carbonaceous partings, in lines though irregular.
3	„	6	„	Grey clunchy clay.
15	„	0	„	Thick, massive sandstone.

Fault—heads E. 30 N.: beds below the fault, dip 10°—N. 25 E.

0	ft.	0	in.	Red and green shale, only the top seen.
7	„	0	„	Sandstone somewhat earthy, white, and fine grained with a few carbonaceous markings on the partings.
4	„	6	„	Grey and red-grey clunch-clay or mud, with many jointings; has not much of the nodular character.
0	„	9	„	More flaky and finer ditto, with reddish hue.
2	„	6	„	Shaly clay with some sandy partings, grey.
1	„	0	„	Cloddy shale, grey.
1	„	0	„	to 2 feet. Sandstone greyish white.
0	„	6	„	to 1 foot. Shaly clay, reddish.
1	„	6	„	Flaky sandstone, with carbonaceous partings.
2	„	0	„	Red clay 1 foot 6, grey clay 6 inches; varying in thickness red and grey alternating.
2	„	6	„	to 3 feet. Sandstone,—whitish, soft.
2	„	0	„	Blueish grey clay, or mud.
7	„	0	„	White sandstone.

dip regular. N. 30 E. 10° to 12°.

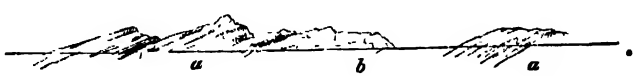
Remarks on Section.

This may be taken as a typical section of the Lower Damuda rocks of the Upper Deinwa drainage, but it is perhaps exceptional in exposing so great a thickness uninterrupted by a trap dyke. A vast number of these traverse the rocks here, and much might be said of

Prevalence of Trap Dykes.

the manner of their occurrence. Most remarks bearing on this subject will, however, be reserved for the part of this paper of which the Trap rocks will form the subject. Meanwhile it may be noticed that one of the most remarkable features connected with these dykes is the slightness of the mechanical effect produced by them on the beds of the sedimentary rocks.

Fig. 6. Sketch Section illustrating relations of Trap and associated beds. *a*, *a*, Are flags and sandstones and shales. *b*, Trap.



The beds, on which the trap rests, are not seen at the surface, but those resting on it are well exposed, and these, at the junction of the two rocks, are baked to a porcelain and hardened to a distance of 3 inches from the surface of the igneous rock, which itself is earthy and compact at and near the junction, and highly crystalline away from it. Were it not disproved by this evidence from the lithological condition of both the sedimentary and igneous rocks, it would be difficult to resist the conviction that the beds which rest on the trap had been deposited subsequently to its consolidation; so slightly does its intrusion seem to have affected the *mechanical* condition of the beds.

In the upper Deinwa Valley.

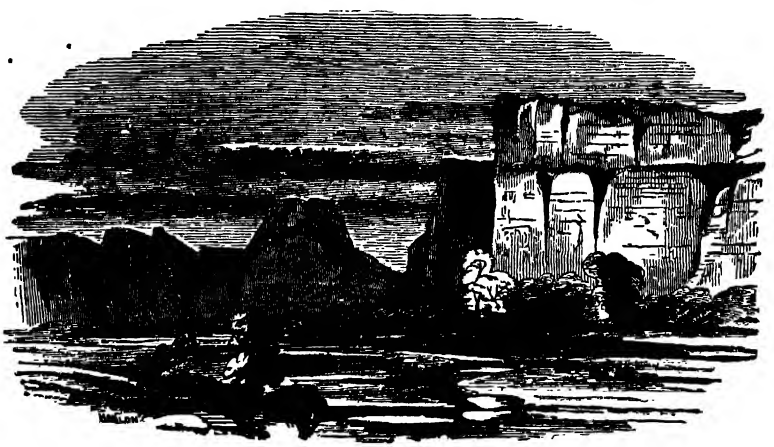
As in the valley of the Tawa, we here find the rocks of the Talcheer and Lower Damuda groups presenting a flat or gently undulating surface, from which the massive vertical scarps of the Mahadeva sandstone rise.

The sketch given on the next page fig. 7, illustrates this. The low ground here being occupied by the beds of the sub-divisions *d*, and *e* of which the above measured section gives an example.

With regard to the thickness of these beds, as seen here, what has been already said will suffice to point out how difficult it has been found to

arrive at a fair estimate. It may be well to mention, however, that we believe there is sound reason to think that several hundred feet of thickness are really here exposed—a conclusion at variance with that arrived at by Mr. Hislop. That geologist, in a paper in the Jour. Asiat. Soc. Beng. Vol. XXIV, p. 347, gives the thickness of the rocks below the Mahadeva sandstone at 85 feet.

Fig. 7. Mahadeva Hills, seen from the valley of the Upper Deinwa.



Returning to the Nerbudda valley, and proceeding eastward to the gorge through which the Sita Riva River escapes from the Hills into the plain, the following section is exposed:—

Fig. 8, Section in Sita Riva glen.

1.—The conglomerate of the Mahadeva group nearly horizontal, overlies, unconformably, the lower Damuda rock.

2.—50 feet of *grey* thick bedded sandstone with bands of red and blue shale—dip 15°—E. 5° N.

3.—10 feet of coal.

4.—30 feet of hard grey micaceous flag stones.

5.—16 feet, 7 feet grey and blue shales; 2½ feet earthy coal; 1½ feet sandy grey shale; 5 feet coal; dip—25° E. 35° S.

From 5 to 7, 180 feet of sandstone—flags, some being hard micaceous, and some coarse and friable, and some bands pebbly.

6.—6; places where shales occur among the above; at both the shales are very carbonaceous, and at one there is a thin layer of coal; in both the shales contain vegetable impressions.

7.—A trap dyke.

8.—A break in continuity; may be caused by a small fault.

9.—Green mud and earthy sandstone, boulder bed, and conglomerate. Dip irregular, but reversed to the N.

10.—Trap dyke, probably marks a small fault, the beds to the north of it dip at a much higher angle than those to the south. These seem to be the same; both are earthy sandstone.

11.—Coal 4 feet.

Close to this coal band a bed of brown earthy sandstone abounds with Glossopteris and Phyllotheca, some blue and grey shales are associated; these beds are vertical.

12.—The above beds pass on into other similar strata which begin to dip S.

13.—The same beds apparently now dipping N.

14.—Trap lying against them.

It is not clear whether it rests on them or is faulted against them. A small outlying patch of the Mahadeva conglomerate is shewn, which has been faulted against these shale beds here. The amount of this fault is probably very slight, as the Mahadeva conglomerate was no doubt deposited on the denuded surface of these very beds.

Remarks on the Sita Riva Section.

This is one of the longest known and most valuable of our sections; the coal exposed (all the seams taken together) is 19 feet thick, and most of it is of very good quality. All the beds south of the trap dyke 7, we believe to belong to the (*d* and *e*) lower sub-divisions of the Damuda: (*f*) the upper not being represented at all: all the beds north of that dyke we consider as belonging to the Talcheer division (*a*) (*b*) and (*c*) of the same list (page 148.)

This dyke (No. 7) certainly has not shifted the beds, nor does it mark a fault, for the green earthy sandstone is seen both north and south of it, and on the south appears to underlie conformably the flags and sandstones of the upper part of the section. All direct connection is however cut off by the fault, which probably occurs at 8, on the north of which we find the Boulder bed. This displacement need not however have been great, for the beds close to the dyke 7, are such as ordinarily accompany the Boulder bed, (the *b* of our list.)

Obscurities in superposition.

Below this point it will be seen from the diagram, *Fig.* 8, that the rocks exposed are greatly contorted, the dip being several times reversed in direction; and the stratigraphical relation of the beds among themselves is not clearly made out; these are extremely obscure, and there is much in the aspect of the series of beds below (*Fig.* 8,) the break at 8, which seems to suggest that they may belong to an older series than those above (to S. of) it, that is (the upper series being Lower Damuda, and the lower Talcheer) that there may be here evidence of unconformity between these two sets of beds. This is only a suggestion however, and is rendered doubtful by the occurrence at 11, of fossil remains

Possible unconformity.

which have all the aspect of being identical with the plants of the Lower Damudas.

Disturbance and denudation.

We have in this section a striking example of the great disturbances which affected the Lower Damuda and Talcheer rocks and of the vast denudation to which these have been subjected, prior to the deposition of the Mahadeva group.

Better sections to the East.

It is however far to the north-east, in the valley of the Mahanuddi and of the Johilla Rivers, and principally in the latter, that the best section of the Lower Damuda and Talcheer groups are found. (See map.)

In the banks of the Tawa, and of the Sita Riva their richest coal seams are laid open, but in the valley of the Johilla, where the river runs nearly at right angles to the strike of the beds, a section, several miles long, is seen, and a thickness of not less than three thousand feet of those formations exposed. The boulder bed lies at the base of the series here also, and the green muds (the *a* and *b* of our list) are seen to pass up into earthy sandstones: these are succeeded by, and interstratified with shales and flagstones (the *d* and *e* of our list) among which some thin bands of coal occur, and some of the shales contain numerous impressions of Glossopteris and Phyllotheca.

Johilla River Section.

Perfect continuity and great thickness.

In this place we have, in unbroken continuity, a section showing representatives of all those beds which we class under the heads of Lower Damuda and Talcheer. The sequence seems uninterrupted; and complete conformity seems to obtain from the base up to the highest beds. No where can a line of separation be drawn between the Talcheer and lower Damudas; and the presumption is strongly in favor of the whole forming, here, one group.

Same Rocks found far to the E.

It may be desirable to mention here, that in the country (beyond the limits of our map) to the east a very similar arrangement of these rocks obtains. Lower Da-

muda and Talcheer rocks have been found in the Singrowlie district and the sub-divisions *a*, *b*, and *c*, seem to be considerably developed there.

From among *these* coal has been for some years extracted, and the works are carried on both in open quarries, and by pits sunk to small depths on the beds.

Professor H. B. Medlicott (of Roorkee) reporting on this district in 1854 describes these rocks thus:

"In the Sukneya Nuddi between Miru and the Rehund, and also "at the bottom of Mr. Burke's new pit, there is "found a green mud which breaks into cubical "fragments, and is much traversed by seams of calcareous matter, prin- "cipally on the joint surfaces; it often contains "pebbles of the old crystalline rocks, and some- "times boulders of these of considerable size, occasionally weighing many "tons."

Talcheer of the Sone valley.

Boulder-bed.

The stratigraphy of lower groups.—Within our area, these Talcheer and lower Damuda rocks have been subjected to considerable mechanical violence, but with reference to the former the general or total absence of bedding renders it very difficult to come to any positive conclusion as to such disturbances. These amorphous deposits are however found to be traversed by those lines of "fault rocks," which elsewhere are known to be the result of displacement of the beds across which they run, and to mark in some cases, very considerable vertical shifts of those beds. These brecciated lines are developed among the green muds quite as frequently as elsewhere, and it may, we think, be presumed that among these, they indicate faults as great in vertical movement as similar brecciated lines are known to do among the well bedded portions of the series, where the amount of such movements can be to some extent seen, though often, as has been stated, but roughly estimated.

Probably great disturbance of the Talcheer.

Suggested by the fault rock.

Also by Trap Dykes.

Again, among the Talcheer beds trap dykes are very frequently seen; and the same considerations as those just now offered seem here also to be applicable. Those dykes which have been noticed among the clearly bedded rocks are sometimes, though not universally, seen to produce violent *disruption* of the masses among which they have been forced; and there seems to be no reason why similar dykes among the amorphous Talcheer should not have been accompanied by similar mechanical violence. Still little definite can be said of the movements, which have there been shewn by analogy, to have probably affected the Talcheer.

With reference to the lower Damudas, whose flags, shales, and sandstones afford means of observing the results of any disturbances which may have affected them, we have already mentioned the breccia lines, and the trap dykes, in connection with the indications of mechanical violence. It has been found that the former are much more coincident with lines and areas of disturbance than the latter.

Trap dykes dynamically considered.

In many cases it has doubtless occurred that a trap dyke marks the line along which beds have been twisted and broken, and has sometimes perhaps been itself immediately connected with the active cause of ruptures and contortions. This is suggested when we find the igneous rock filling in cracks, and fissures, of the sedimentary rock, along a dyke line, and enclosing fragments of it; but evidence of great disturbance among the bedded rocks by no means generally coincides with great development of igneous action; and *Fig.* 6 (p. 63) shows a case where intrusive trap has exercised or been accompanied by little or no disturbing influence on the flags and shales about it. There are indeed traceable in the district, areas of maximum disturbance, but these coincide, not with the areas of maximum igneous action, but with the boundaries of the formation, and it is also near those boundaries that the

Areas of maximum disturbance.

Coincide with those of breccia.

great majority of the lines of breccia are also to be found.

The localities already described will furnish examples of this. Returning to Rawundeo, the rocks exposed near that place, in the Tawa, are considerably contorted and disturbed; and the dips which are often at high angles, are often reversed, but passing towards the north, that is away from the boundary, evidence of contortion and disturbance becomes gradually less and less apparent.

Cases of disturbed areas.

1st case.

Again, in the Machna, the beds are considerably broken, and bent; but if, from the junction of that stream with the Tawa, we proceed down the latter, to the N.—that is away from the boundary of the crystalline rocks, the beds gradually approach more and more to the horizontal.

2nd Case.

Again, in the Sita Riva section at Mopani, see Fig. 8, the beds are less and less disturbed in proportion to their distance from their N. boundary. The dip decreases from the vertical beds seen at the north end of the section, to one of 15° where the Mahadeva conglomerates overlie them on the south, and in the Johilla section precisely the same conditions are again repeated.

3rd Case.

It will hereafter be shown to how great an extent the boundaries between all these sandstone formations and the crystalline rocks, are faulted, and no doubt the movements, which produced this break in continuity of the beds, have also extensively influenced the stratigraphical condition of the Talcheer and lower Damudas, disturbing them in the vicinity of these boundaries, and of course, affecting them in inverse ratio to their proximity to them.

Age of denudation of lower Beds.

It is certain that the lower Damuda and Talcheer groups were much disturbed prior to the deposition both of the Mahadevas and also to that of the upper Damudas. The Mopani section (see Fig. 8), shows this very clearly for the Maha-

devas; and in the valley of the Johilla, a section exposed near the village of Bowri, shows the bent beds of the lower Damudas faulted against the syenite of the country, where the junction between these is overlaid horizontally by the upper Damuda beds; indeed many places in the Johilla valley and also in that of the Mahanuddi, show very well this kind of unconformity between the lower Damudas and the fossiliferous shales of the upper Damudas.

Also to that of the upper beds.

The occurrence of isolated patches of the crystalline rocks surrounded on all sides by the beds of the lower Damudas, has not unfrequently been noticed in our district. Similar facts have been observed in Orissa, and have been differently accounted for by different observers. It has been supposed on the one hand, that they were due to inequalities of the surface of the crystalline rocks at the time of the deposition of the lower Damudas, that is, they may be the tops of the highest parts of that surface, down to the level of which a recent denudation has now worn away the beds which once covered them; and on the other hand, they have been accounted for by faults. In Central India the latter case occurs very frequently; and although, perhaps, not all, still certainly most of the isolated patches of the crystalline rocks are bounded by such faults. A case where the fault can actually be seen in section occurs in the Mahanuddi river near Peberna village: and in many places we are led to conclude that the boundary is really a faulted one, by the rectilinear direction of the boundary of the patches themselves, and by the fact that this direction is independent of the strike of the crystalline rocks, being, on the contrary, parallel to the general direction of the boundary of the sandstone and crystalline formations, itself a fault.

Outliers of the crystalline rocks.

Two modes of explaining their occurrence.

A probable case of the former supposition occurs in the Hirun in the upper part of its course, near the village of Narrainpur.

§ 6. *Upper Damuda.*

It has been already stated that in the Johilla valley the lower Damuda beds are seen to have been disturbed, extensively denuded, and to be now unconformably overlaid by those to which we have given the name of the upper Damuda series. These latter are here made up of clays and earthy sandstones, often massive, but generally more or less laminated, generally very soft, but occasionally and locally considerably indurated.

Description of the upper Damuda.

The prevailing colors are lavender grey, and yellowish white, and the beds are in some places very fossiliferous. The fossils are all vegetable. The general aspect of these plant fossils is very distinct from that of the flora of the lower Damudas; the vertebraria, glossopteris and phyllotheca of the latter are no longer found, but they are replaced by several cycadeous plants, with some conifers and lycopodites. It cannot as yet be confidently asserted that none of the species of the lower group occur in the beds of the upper, but it is certain that the prevalence of certain forms to the exclusion, more or less complete, of others, characterizes in a very marked manner each of these series of deposits.* In Central India the two formations are clearly separable on stratigraphical grounds, and their unconformity has already been stated to be clearly seen.

Lower and upper Damuda flora distinct.

To what extent mutually exclusive.

Unconformable in Johilla valley.

In the Mahanuddi valley this is even better seen; there the upper Damudas occupy a larger area; better sections of them are found; and both the fossils and the lithological characters of the formation can be well studied.

Also in the Mahanuddi valley.

In the neighbourhood of Jubbulpore beds lithologically identical with those of the Mahanuddi are again pretty well exposed. They may be traced along the base of the

Near Jubbulpore.

* The collections in the Calcutta Museum do not furnish a single common species.

trap topped hill east of the station, and appear at the little hill on which the Jogi's hut is built. Many fossiliferous beds have been detected in this neighbourhood, and the plants are the same as those of the Mahanuddi shales; here however no rocks belonging to the lower Damuda group are exposed, and the shales and sandstones which represent the upper division rest on, and are faulted against, the crystalline rocks.

Between Jubbulpore and the Mahanuddi.

From the Mahanuddi all along to Jubbulpore, a narrow strip of these rocks has been traced (see map), and fossils found in several localities; but the Lameta beds (and over them the trap) overlapping these on the south, leave but a very small area of them exposed between themselves and the faulted North boundary of the upper Damudas. Passing from Jubbulpore south west down the Nerbudda valley, these rocks are pretty continuously seen along its south side, as far as the meridian of Nursingpore, and I shall now proceed to describe a section found in the Sher river, 12 or 14 miles east of this latter station.

Sehora section.

Close to the village of Sehora (see map) the crystalline limestone of the schist series is found to be brought by a fault into contact with—

An earthy green and brown sandstone, pebbly and sometimes sufficiently so to be a conglomerate.

This is the lowest bed seen of the upper Damuda group here. Ascending the stream, and ascending also in geological succession, we find resting on the above,—

An earthy friable sandstone, with carbonaceous markings and some irregular carbonaceous partings;

A brown sandy shale (laminated) with regular carbonaceous layers, and a band of coal 6 inches thick where best seen, but thinning out to 4 inches within a few feet along its outcrop;

Over this, a band of fine grained brown sandstone;

4 inches of Coal;

A layer of carbonaceous shale;

Brown fine grained sandstone;

Massive beds of grit and sandstone free from argillaceous matter.

These beds are all so irregularly bedded that it would only mislead to give to each a measured thickness: the aggregate of the whole may be from 60 to 80 feet.

Remarks on the sections.

Near the fault they seem slightly tilted up, and dip at low angles to the south. This dip however, soon vanishes, and at no great distance up the stream it is reversed; above, the beds roll in gentle undulations from north to south.

Ascending the stream they appear here and there, just above the level of the water, but are, for the most part, covered by the massive thick-bedded grit and sandstone mentioned in the above list; they are, when seen, earthy sandstones, and sandy shales, with carbonaceous partings and occasionally a thread of coal, and the detailed section given very well describes the general characters of the little group as here exposed.

Its continuations.

These are lithologically somewhat like the shales of the Mahanuddi, and also like those near Jubbulpore though not so similar to either, as those of each of the above localities are to the other. The principal difference is the introduction here of the carbonaceous element, elsewhere absent, but the plants which abound in these Sher river beds, are very similar to, if not specifically identical with, the fossils found in the similar beds to the east. The general aspect of the remains is the same, and, as a group, they contrast strongly with the flora of the lower Damudas. There, as at Jubbulpore, none of the beds of this latter division are found.

Compared with other sections.

Identity of the fossils.

About a mile above, where the Machiriva river joins the Sher, and not

Further continuation of the sections.

Coal.

far from the village of Murpipria coal is found again among the upper Damuda beds; and the following section of the rocks containing it will illustrate the general character of the formation. (*Descending*)

Murpipria section.

Thick bedded grits.

A. 10 inches of good pure coal, dip 5° to 15°. S. 30° E.

B. 3 feet soft sandstone.

C. 3 feet (*a*) 6 inches black micaceous shale.

(*b*) 2 feet coal.

(*c*) 6 inches shaly coal.

D. 3 feet hard sandstone.

E. 4 feet fine blue clay, sometimes laminated, sometimes with a complicated jointing.

The outcrop of these beds is only seen for a few yards along the stream, but before their dip causes them to disappear below the surface, they have considerably changed in character, the lettered sub-divisions above given have all altered in value; B. has thickened at the expense of C. In one place the coal A. divides, and encloses a long flat lenticular shaped mass of grit similar to that which covers it. The sandstone B. absorbs the top shales of C. altogether, and the lower layer of shale of the same section also vanishes, leaving from 18 to 22 inches of good coal between two bands of sandstone.

Remarks on section.

Inconstant character of the rocks.

B. and D. are mostly identical in composition, micaceous sandstone; sometimes soft, sometimes hard, and generally so carbonaceous as to be quite black, often with an obscurely laminated structure.

Farther on, A. and B. have both vanished, and are replaced by 3 to 4 feet of grey, and blue, laminated mudstone, or sandy shale resting on C. C. itself has expanded a little, but now encloses about 4 inches of shale in its middle.

The whole outcrop here described is about 150 yards long: in ascending the stream, shale and even coal is again seen just above the water level, but no identification of these isolated little outcrops can of course be attempted.

Continuation of section.

Farther to the west, the Hurd River, about 3 miles south of the Village of Hutnapur, (see map) exposes some beds in which the characteristic fossils (Conifera and Palæozamia (?)) of the upper Damudas abound.

Hurd Nuddi.

The lithological features are here still more unlike those of this formation in its typical localities, than were those found in the Sher river section.

Instead of the soft clays, shales, and scarcely consolidated sandstones, we here have massive, thick bedded, hard, ferruginous grits, and sandstones, with hard, micaceous, and very carbonaceous, black, and blue, shales.

Compared with other sections.

The following section is in ascending order, and commences with the lowest shale band exposed.

Hurd section.

Massive sandstone, dip 20°, S 45° E.

Blue earthy shale, carbonaceous markings.

5 feet fine grained hard sandstone.

10 „ shale, grey-blue, micaceous near the top; a 3 or 4 inch band of ferruginous grit. Vegetable impressions, and carbonaceous layers abound throughout. Between the grit band and the top of the shale 2 threads of coal, each 2 to 3 inches thick, they are very irregular and both thin out into the shale.

2 „ Sandstone.

3 „ blue carbonaceous shale, with a 4 inch band of rich hæmatite.

20 „ a single sandstone bed.

7 „ grey and blue carbonaceous shale, with many plant impressions.

10 „ Sandstone, one bed.

1 foot Coal, varying from 10 to 14 inches in thickness, about 10 yards of outcrop seen, within which it varies so greatly in quality as to be frequently only a carbonaceous shale.

2 feet Sandstone with carbonaceous layer, nodules of pyrites.

3 „ Black shale.

4 „ Sandstone, hard, red and with many nodules of pyrites.

1 foot 6 inches, black shale with many carbonized plant impressions.

Thick bedded sandstones.

In none of the previously mentioned localities is there any difficulty in separating those beds characterized by the upper Damuda plants from those on which they rest, and from those which overlie them. In the Mahanudi valley their boundary below is well marked, and the Lameta beds which there rest on them are so contrasted in lithological character, that although no visible unconformity exists (both being quite horizontal) they cannot be confounded together. At Jubbulpore the same remark holds good. And in the Sher section although the great sandstone beds which cover the shales may turn out to be the remnants of the Mahadevas, yet so (comparatively) little of them is seen, that it is immaterial in that place to settle the question positively.

Remarks on section.

Compared with other sections.

In the Hurd section it is far otherwise, the plant bearing beds are laid bare in the bottom of a deep narrow glen, above them the great sandstone and conglomerate of the Mahadevas rise in steep, (often vertically scarped) high hills, immense fallen masses from which crowd the gorge, so as to hide or obscure the section in most places. The thick sandstone beds which underlie these Mahadeva rocks, interstratify with, and cover the plant bearing shales, are lithologically similar to the Mahadevas themselves, and it has been found impossible to separate them from these. Still certain considerations would seem to suggest that there may be a slight unconformity between the beds forming the hill sides, and those

Unconformity not traceable in this Hurd section.

containing the plants below. These latter are cut off on the south by a fault, and, as far as they are seen, have a decided, though slight dip to the south east, whereas the Mahadeva beds are here persistently horizontal. Higher up the stream, the upper Damuda plant beds have been traced, and the sandstones there overlying them, though apparently part of the Mahadeva series, seem to have been affected by the movements from which these have suffered, and which have bent their beds, and given them their undulating dip. But the fact that the whole district has been violently disturbed subsequently to the formation of the Mahadeva rocks (as the faulted boundary of those rocks proves to have been the case) must necessarily greatly obscure the unconformity between them and any of the older rocks on which they rest: and it will readily be percieved that when original unconformity was slight, lithological character similar, and subsequent movements considerable, the difficulty of separating the groups must be naturally very great.

Pseudo-conformity, accounted for.

Indeed it is probable that close search might detect patches of upper Damuda rocks intercalated between the lower Damudas and the Mahadevas in places where they have hitherto escaped observation. Some of the carbonaceous shales of this group may have been included among those of the lower Damuda set, and some of its massive sandstones among similar beds really part of the Mahadeva series.

Nowhere in this district has the upper Damuda group been seen to attain a thickness of more than 150 feet, where any approximation to measurable limits can be assigned. But we have much to learn on this subject still and many doubts remain to be cleared up. The lithological characters of the group have already been shown to be very various; and the plant remains are relied on as sufficient to identify the beds of the Hurd glen with those of the Mahanuddi valley in spite of the differences, above pointed out, between the rocks of the two localities in other respects.

§ 7. *Mahadeva Series,*

(a) Lameta Group.

General remarks.

In the foregoing pages allusion has more than once been made to a frequently observed and remarkable group of rocks, under the name of Mahadeva sandstones. The range of hills which forms the south side of the Nerbudda valley is formed of these; and along much of that part of the valley which extends from Jubbulpore to Hindia and Seoni, (see map) they form a series of escarpments quite as remarkable, and more picturesque, since less regular, than do those of the Vindhyan range on the north. In the central portion of this range they attain their greatest development, and form the fine masses of the Puchmurri or Mahadeva hills from which their name has been taken. Here they present a thickness of at least 2000 feet; and many miles away from this central culminating mass they still attain very considerable development. At Jamghur hill on the south west, and in Chatur Doria to the north east, from 800 to 1200 feet of these rocks are seen, and still farther in the latter direction Nimbnagur hill exposes not less than 1400 feet. From this towards the east, however, they commence to die out, and east of the meridian of the Sher river (see map) little more is seen of them. This last remark however applies to the lower part of the group, or that which is here called Mahadevas, as distinguished from the upper, or as we have named it Lameta group: the beds of the latter stretch away far to the east and cover large areas in the Johilla valley, (see map.)

Lithological description.

Lithologically considered, the Mahadeva group consists of sandstones and grits, with a few exceptions hereafter to be described. In their typical localities these grits (thick and thin bedded) make up the whole thickness of the formation as seen in the Mahadeva hills, and are characterized throughout, but more especially near the top, by hard earthy ferruginous partings. A very prominent characteristic of the Mahadeva area is the way in which these great sand-

stone masses are disposed; vertical escarpments with clear rock faces many hundred feet high, are constantly met, and this remarkable feature is presented wherever these rocks are (in this district) found. The sketch given in Fig. 7, p. 168, is a view of the south face of the Mahadeva hill itself, where the finest of these escarpments is well seen, rising from the flat ground of the Deinwa valley. To the west, the prolongation of the same range often presents a sheer precipice very nearly as high as this one, and frequently far more continuous. A very remarkable glen by which the Sonbudree river flows north to join the Tawa, gives a most striking case of vertical escarpment. In this place the nearly horizontal bedding of the sandstone is clearly marked on the nearly flat vertical surface of the precipice, by lines apparently quite straight, and traced by the hard iron-earth partings above alluded to. These partings form quite a feature in the rock of the summit of Belkunda Peak, a few miles to the west, and one of the culminating points of this range. Here the ferruginous earth, besides forming regular layers at intervals through the sandstone mass, was irregularly disseminated. Sometimes it forms nodules, sometimes hollow tubes or cylindrical pipes of different diameters, sometimes waved layers like rippling. This ferruginous earth has now assumed a pseudo-vitreous texture, and looks on the fracture like rude pottery.

Escarpment.

Ferruginous partings.

Strange appearance they give rise to.

From their superior hardness these bands have resisted denudation better than the surrounding sandstone, and they now stand out from its surface, often giving a honey-comb aspect to the rock, and affording facilities for climbing, without which it would be totally impossible to reach the top of the isolated peaks such as Tek Belkunda, Chaorigurh &c. Round the foot of the highest points of these hills great quantities of broken fragments of these iron clay aggregations lie strewed over the ground, and closely resemble heaps of broken drainage tubes and tiles.

Varieties of bedding.

In some parts of the country these sandstones are much less regularly bedded than in the Mahadeva scarps themselves. Unbedded masses, a hundred feet thick, are often seen, and false bedding among these, is very common, and often very complicated and capricious.

Fallen blocks.

Some of the glens are crowded with large blocks of the beds which are exposed high up the hill side, as has been already noticed with regard to the Hurd glen; and some of these fallen fragments are of very great size; one was measured which amounted to 5560 cubic feet.

Sometimes the great sandstone masses weather out into very oddly shaped hills. The highest peaks of the Puchmurri group, as seen from the plain of the Nerbudda valley, offer a remarkable instance of this. From this, as indeed more or less from all sides, these summits assume a variety and grotesqueness of outline which must strike any one passing along the road from Nursingpore to Hosungabad. The sketch *Fig.* 9

Fig. 9

is a view of a fine hill called Burimai, detached from the Puchmurri

mass, but formed of apparently the continuation of the same beds, and which may be considered as an outlier of the great mass and affords an example of the manner in which the Mahadeva sandstone sometimes weathers away from the long escarpments which it commonly forms.

Resuming the lithological description of the Mahadeva group, the portion next in importance after the great sandstones, is the great conglomerate series.

The Mahadeva conglomerates.

All along the south side of the Nerbudda valley from Lokurtullye on the west, to the Sher river, the hills are formed mainly of Mahadeva rocks. These sometimes rest on, and are often faulted against the crystalline schists, which with their associated igneous rocks are often found to form the base of the hills, and to reach a height of 200 or 300 feet above the level of the valley, above which height the Mahadeva rocks almost always appear. Along this line of their northern boundary, the Mahadeva group always has a conglomerate at its base. This conglomerate may be found forming the sides of almost all the glens of the outer range, and may in them be well studied. At Hinhotia and Dilheri it has a calcareous base for the most part, and the 600 feet of it seen in the former locality is pretty uniform throughout in general character: in the latter only a small thickness is observed, the sandstone soon coming in.

Peculiarities of the conglomerate.

It may be here remarked, that this calcareous character of certain of the Mahadeva beds, of which this conglomerate at the base is an instance, (less remarkable however than another portion of the series to be hereafter described) may perhaps be connected with the occurrence of great limestone accumulations among the old crystalline rocks. The calcareous portions of the Mahadevas are strictly confined (as far as is known) to the near vicinity of the northern boundary of the group along which boundary the crystalline limestone abounds, and it is certain that the occurrence of a calcareous

matrix in the conglomerate almost always coincides with those places where the schist-limestone outcrops at or near the junction of the two formations.

Choarigurh conglomerate.

At the old fort of Choarigurh (see map), 20 miles S. W. of Nursingpore, a set of low hills are composed of the conglomerate. Here it is formed exclusively of white quartz pebbles, held together by a minimum quantity of a red sandy earthy matrix; all the pebbles are small; the largest not exceeding 3 inches in diameter.

Nimbnagurh conglomerate.

At the base of Nimbnagurh hill, on the contrary, there may be noticed near the village of Berair many such large fragments in the conglomerate. 2 feet in diameter is a common size; and these are often very angular and little worn. In this conglomerate blocks of many varieties of the schists were noticed, besides granite, syenite, and greenstone, also bedded in a brown felspathic sandstone base. The hill shows a clear section of about one thousand feet of this Mahadeva conglomerate and although as we ascend, sandstone bands are more and more frequently intercalated, yet many pebbly layers are found up to the very summit.

Hutnapur conglomerate.

Near Hutnapur the crystalline rocks are found to a height of at least 300 feet above the valley level where the conglomerate beds rest on them. The crystalline limestone here supports the Mahadeva rock, the matrix of which however is not calcareous, although containing many fragments of the schist limestone. There, as at Nimbnagurh, the conglomerate at the hill base is found to contain large and little worn blocks, which are not found higher up; in the upper beds the size of the fragments becomes gradually less, and they are more rounded, until at top only a few pebbly bands occur in the sandstone of which the mass is there made up.

Conglomerate becomes finer in the upper beds.

But besides this, if any bed of the true conglomerate portion be follow-

ed along its strike* to the south, (that is away from the boundary) which may be done in the valley of the Hurd, the same change in its characters is seen to obtain, that is, it becomes less coarse, in proportion to the distances from the boundary, and finally passes into the ordinary sandstone.

Also in receding from boundary.

Thus it appears that the present boundary of the Mahadevas, along this part of the hills, coincides or nearly coincides with the shore line of the area of deposit of the formation. The conglomerates mark this shore: large angular fragments of rocks which occur close by, are embedded in the comminuted detritus of these rocks themselves; while elsewhere ancient shingle beds show where the wave action has ground down the blocks submitted to its influence, until only small rounded pebbles of their hardest portion remain.

Mahadeva Boundary a shore line.

It was stated above that the calcareous portion of the Mahadevas was, like its conglomerates, apparently confined to the vicinity of the northern limits of that formation, and these calcareous portions may conveniently be taken as a third subdivision of the group *lithologically* considered, subordinate however to the sandstones and conglomerates above mentioned.

Calcareous section of the Mahadevas.

About 15 miles west of Patroda (see map) a stream issues from the south escarpment of the valley through a fine gorge, at the mouth of which the village of Sali stands. The Mahadeva sandstones and conglomerates which form the steep sides of this glen are all calcareous to some extent, and are interstratified with lenticular bands of what may be called a siliceous indurated marl, or an impure sandy limestone, or else a calcareous sandstone, as this or that ingredient predominates.

Sali glen.

To the south, the calcareous element predominates much, and for a

* By the *strike* is here meant its out-crop along the steep and often precipitous sides of the glens. The beds are nearly horizontal, and thus a single bed can be often followed for a considerable distance.

thickness of from 500 to 600 feet, the series is made up of thick bedded limestone, mostly pure, but in parts recurring (as it were) to the mixed character above noticed.

The minor calcareous bands were stated to affect a lenticular arrangement, and it is found that this rule holds good on the great scale and is true even in the case of this very great development of the limestone. A spur of the hills, 600 feet high, is composed, as described, exclusively of limestone, but the neighbouring spurs are found to present a mixed character, and to show the limestone interstratified with many layers of sandstone more or less calcareous.

Not more than a mile from the limestone hill just noticed another is found in which the calcareous bands are so few as to be almost overlooked, and were it not for the transitional character noticed elsewhere, it would be difficult to escape the conviction that a fault must have brought into their present relative positions masses of rocks so very dissimilar in lithological aspect.

Chatur Doria.

Futtipur village stands a few miles north-west of the hill called Chatur Doria (see map).

Fig. 10.

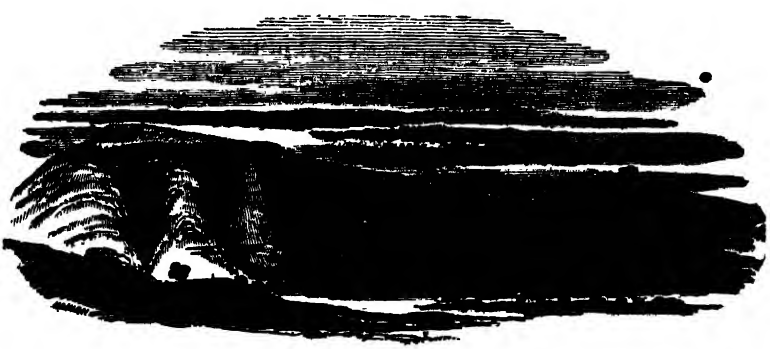


Fig. 10 is a sketch of this hill as seen from the south west, looking across the flat ground of the Talcheer and lower Damuda shales, from which the hill rises to a height of 1200 feet. Ascending this hill from

the nearest spurs as seen in the sketch, that is from the south west side, limestone similar to that of Sali glen is passed over, to a height of about 500 feet. At the base the section is of the mixed character, the limestone being interstratified with sandstones; and toward the top of the 500 feet, the same fact is repeated; indeed, the limestone dies out rather more rapidly here than below, and is succeeded above by thick-bedded sandstone which continues to the summit of the hill.

Description of Chatur.

At the height of about 400 feet above the plain a very strong bed of the limestone is found, the out-crop of which on the hill side, is well seen from a distance, owing to the fact of its lying between some layers of half indurated marl, or soft earthy limestone. This bed is shown in the sketch (*Fig.* 10, p. 189, and may be there perceived to have a slight dip to the north-west; this dip is quite imperceptible in detail, and its amount could not be measured at any point of the out-crop, but is notwithstanding sufficient to bring this bed which is 400 feet above the valley on the W. of Chatur, close to the top of the more distant peak of Doria (see sketch.)

This calcareous portion of the Mahadeva formation is in its extent, whether thickness or surface-area be considered, a very insignificant part of the group, but it is invested with a special interest by its similarity to the sub-group which we have provisionally named from the Lameta Ghât on the Nerbudda, and which will be more fully described hereafter.

Connection of these beds with the Lameta group.

No traces of the remains of any animal organism have as yet been found in the Mahadeva beds. Much silicified wood (stems &c.) is contained in some parts of the sandstone of the series, and in a glen behind Nimbnagurh hill, and opposite the mouth of which Kuluri village stands, were noticed what may be called "fossil timber." Trunks of large trees are embedded in the thick bedded sandstones: several of these were 14 to 16 feet long, with a diameter of 2½ feet and

Fossils absent.

Fossil Timber.

3 feet respectively. These are not "*silicified*" but regularly fossilized by the sandstone itself. The replacing material is coarse, and the structure of the wood but feebly traceable. The medullary rays and bark of an exogen are however distinctly recognizable.

Lower limit of the Mahadeva.

It is certain that the lower Damudas were largely denuded before the deposition of the Mahadevas, and it is, at all events possible, that even the upper Damuda may have also been disturbed and denuded before the same period: in spite of this the tracing out of the lower limit of the Mahadevas has been found a work of great difficulty. This subject has been already enlarged upon when the boundaries of these lower formations were under discussion.;

Hurd River section.

and in describing the Hurd coal section it was pointed out that the massive sandstone beds which interstratify with the coal and shale bands are undistinguishable from those of the Mahadeva group themselves. Higher up the Hurd, a thick bed of sandstone, apparently Mahadeva sandstone is seen, near

Monighât section.

the villages of Cachar and Monighât, resting on a series of flags, shales, and thin-bedded sandstones with plant impressions, and which seem naturally to find their place in our Upper Damuda division. The thick sandstones seem to pass up into the great mass of the typical Mahadevas, and altogether it seems pretty certain that here at least, we have the division line between the two formations.—But in many ways this line is very ill defined; a kind of pseudo conformity is preserved, and no definite difference of lithological character exists.—However the general prevalence of such conditions may increase the difficulty of laying down accurately, in detail, the position of the line of demarcation between the Mahadeva and the lower and upper Damuda groups, in some places, yet this unconformity on the great scale already noticed, and the great differences in the lithological characters of the groups *taken as a whole*, amply make up for this deficiency of precise evidence in individual cases.

As far as the lower Damuda beds are concerned, the Morun River section near Lokurtullye, and the Sita Riva section above Mopani, both of which have been described, are satisfactory. And with reference to the upper Damuda series, the lithological characters and the fossils, seem sufficient to warrant the separation of the two groups, and even if hereafter we find that the interval indicated by this separation is not really so great as we now suppose, it must still remain a positive separation nevertheless.

Mahadevas and lower Damuda.

Mahadevas and upper Damuda.

If the upper Damuda and the Mahadeva rocks appear, when more fully worked out, to belong to the same geological series, still the two must be kept to some extent distinct, the former as the lower, and the latter as the higher stage of the group.

There is however one consideration which very frequently recurs, and always strongly suggests real unconformity between the Mahadeva and upper Damuda beds in individual sections; and which, when considered in the aggregate of known instances of its occurrence, may fairly be considered confirmatory, if not conclusive as to the unconformity. It arises from the following facts.

Confirmation of above separation.

The geological observer must be struck by the absence of intrusive trap among the Mahadeva sandstone of the Gondwarra range. These are often overlaid by basaltic flows, and dykes do occasionally cut through their beds, but relatively to the subjacent formations, the absence of the intrusive igneous rock is certainly remarkable.

Absence of Trap dykes among the Mahadevas.

The massive, straight bedded and undisturbed, rock escarpments of the Puchmurri range, are continually before the eyes of the explorer of the deep valley on the south of those hills in which he finds a trap dyke under his feet at every turn. Many of these dykes he may trace up to the foot of

Dykes of the lower Damudas do not run up into the Mahadeva.

these escarpments, wherever the talus admits of his making the examination, but very few indeed can be traced into the Mahadevas. The rare exceptions which exist are insufficient to hinder the conviction that the vast majority (at all events) of the dykes which cut up the lower Damuda rocks were intruded prior to the Mahadeva period and underwent denudation in common with those rocks.

Dykes of the upper Damudas do not run up into the Mahadevas.

This belief is strengthened by the explanation it affords of the vast quantity of trap detritus found in many of the Mahadeva conglomerates. Now, although the upper Damudas are certainly far more free from Trap Dykes than the lower Damudas, still several sections show dykes cutting them, and not passing up through the massive Mahadeva rocks above. Near Monighât village (already mentioned) the Hurd exposes beds so circumstanced, and in the Sher river about a mile above the measured section given (page 177,) two fine cases may be observed; in each of which a dyke several feet broad cuts the plant-bearing shales, and both it and they are overlaid by a thick mass of sandstone which is not pierced by the dyke, nor visibly altered at the contact, or rather, near it; for the absolute contact cannot in either case be observed. In the Machiriva again precisely the same thing occurs.

No contemporaneous interstratified trap.

It may here be remarked that no case satisfactorily proving interstratification of any of the sandstones with trap has been observed in this district. This holds good for the lower and upper Damuda formations as well as for the Mahadeva, with which we are at present more immediately concerned.

Pseudo case of interstratification.

The very slight amount of chemical change produced in the sandstone, by the intruded rock, often might lead the observer to mistake for interstratification, the intrusion of trap between two beds of sandstone especially where the termination or thinning out of the wedge shaped mass is not exposed. But it has invariably been found in such instances, that a careful examination has

detected some evidence of the real state of the case, sufficient to prove that the igneous is more recent than the super-incumbent aqueous rock.

In hill spurs near Buddi.

The Doondi river near the village of Pertulla (see map) exposes a section illustrative of such a case. The lower spurs of the range of which Buddi peak is the culminating point present, in many places, pseudo-interstratification of the sandstone and basalt. One may ascend from sandstone to trap, and on to sandstone again, but in every case examined, the gorges between these spurs show that the basalt is not in reality continuous, but that at some distance away from the place first examined, the ascent might have been made on sandstone only.

In Pertulla section.

In the bank of the Doondi river near Pertulla, a sandstone bed at the base of one of the low hills, may be seen resting on trap, on which it lies quite, or nearly, horizontally. When its lower surface is examined no mineralogical alteration can be detected, such as might be expected to result from the bed having been lifted up by a mass of melted rock in a viscous or fluid state. The narrow band of discolored stone at the junction is in no way different from what may be seen between almost any two beds of sandstone; and it is very difficult to escape the conviction that here the sandstone must have been deposited on the consolidated basalt.

Trap really intrusive.

But this was not the case; the trap is really intrusive, the upper bed has yielded a little farther on, to the pressure from below, and the stream now exposes the place where the igneous rock rushed up through a crack in the upper bed, and flowed over it.

The bed was here much broken up, and many fragments of it enclosed in the trap; the whole is now well exposed, and the continuity from the place where the basalt underlies, to where it breaks up the overlying sandstone bed clearly seen. We can also see that where the mechanical violence exercised by the trap has been greatest, there also has its che-

Mineral alteration of the sandstone.

mical action been most strongly felt. The enclosed fragments (though some of them are of great size) and the edge of the fissure through which the trap apparently escaped upwards, are baked to a porcelain or vitrified; although the lower surface of the same bed, only a few feet off, where seen resting on the same trap, is quite, or almost quite, unaffected by the contact; nor does any apparent difference in the composition of the rock in the two places suggest the idea that its liability to suffer from the action of heat was originally dissimilar. It may be remarked here that differences in the texture of the trap itself seem to be equally capricious. In the section just described, the igneous (like the sedimentary rock) seems to be little influenced by the proximity of the super-incumbent mass, which, nevertheless, must be supposed to have had a very different temperature from itself where they came in contact. But elsewhere similar conditions have resulted in very marked changes in the texture of the intruded rock. The upper surface of the trap generally exhibits all the ordinary characters of a dyke wall, becomes less crystalline, often cornean, or even earthy, and divides into thin flakes parallel to the plane of junction.

Mineral alteration of the trap.

Diagram Fig. 6, p. 167, shows another case of the pseudo-interstratification of the trap and sandstone. Here however the overlying sedimentary rock is considerably altered at its lower surface.

Our examination of this district was necessarily insufficient to prove that no interstratification of the traps and sandstones ever obtained, but it may be safely affirmed that such cases, if they did occur, were exceptional.

There are few parts of India which present scenery more picturesque than the Gondwarra Range, included in our map; the Mahadeva sandstone *is the rock of the country*, and its manner of weathering, and the contrast which the ground it covers thus offers to areas, occupied by the *softer* deposits of the Damuda series combine to form landscapes of the most varied outlines.

Some of the features of these landscapes will be seen illustrated in the sketches already given, *Figs.* 9 and 10, and Plate IV; and also will be found further shewn in *Figs.* 22, &c. below.

§ 7. (*a*) *Lameta group.*

Area of the Lameta beds.

It has been stated that the meridian of the Sher river is, as far as we know, the limit towards the east of the Mahadeva rocks. They seem to die out about here, and the hills hence eastwards are no longer formed of their sandstones and conglomerate as are those to the west. In this part of the country their place is taken by the series we have now to describe, that is to say, we find, faulted against the crystalline rocks, resting on the upper Damuda beds, and covered by trap, in this eastern part of our map, not the Mahadeva sandstones but the Lameta beds.

Karyia section.

In the bed of the Sher, near the village of Karyia, some beds of red and green fine grained sandstone with sandy indurated marl are found faulted against the upper Damuda beds.

Farther E.

Very little is seen of them as they are soon covered up on the south by trap, and only a thickness of 20 to 30 feet at most is exposed. From here, however, they stretch in almost unbroken continuity to the east as far as Lameta Ghât on the Nerbudda, where a good section of them is exposed. Near Jubbulpur they rest on the plant shales of the upper Damuda group and are covered by trap, and from thence they are found at the base of the trap hills

To the Johilla valley.

which extend to the north east, and have been traced up to the valley of the Mahanuddi, and thence into that of the Johilla. At Lameta Ghât they are faulted against both the upper Damudas and the mica schists of the metamorphic series, but from hence to

Manner of occurrence.

the east they rest on those rocks; so that their thickness being inconsiderable, and their present boundary being determined by denudation, they are found at the base of, and following all the contours of the trap hills. They thus appear on the map as a narrow strip between the trap and the Damuda rocks.

Lithological description of the Lametas.

Lithologically considered they may be described as follows, the sub-divisions being taken in ascending order as far as possible, but being at the same time strictly lithological, and not stratigraphical.

(*a*) Greenish sandstone, mostly loosely aggregated but sometimes hard and even cherty.

(*b*) The characteristic bed of the series is an impure earthy limestone, or indurated marl of a pale drab, or blueish grey color, often traversed by many vein like cavities which give a tufaceous aspect to the rock, these are often filled with bands or segregations of chalcedonic quartz, or of carbonate of lime. Most frequently the cavities are incompletely filled in a way suggestive of infiltration.

(*c*) Pale purple and pale green muds, sometimes with sufficiently distinct lamination to deserve the name of shale. These are sometimes arenaceous and form earthy sandstone; sometimes calcareous, being then marl.

(*d*) Sandstone with the tufaceous aspect of sub-division *b*, it contains bands and segregations of flint, and sometimes even of carbonate of lime: it is sometimes formed of grains of glassy quartz cemented by a white powdery matrix, friable generally, though in places intensely hard.

Remarks on these sub-divisions.

No single section presents all these varieties, but wherever the base of the series is seen, sub-division *a* is found to underlie all others. It is sometimes brown red in color, instead of green, as near Jubbulpur, where some difficulty is found in

separating these beds from the underlying sandstones of the upper Damudas, which there are friable brown sandstones, and the unconformity being very obscure.

Sub-divisions *b* and *c* are not constant in their relative positions, either indifferently overlying the other; *b* being in fact an indurated form of *c*, with the addition of infiltrated silica or lime.

Sub-division *d* is (like *a*) only exceptionally present. It is well seen under the trap near Jubbulpur, but it again occupies a considerable area in the Mahanuddi country to the east.

Connection between the Lameta and the calcareous Mahadeva.

In describing the lithological characters of the Mahadeva series a set of calcareous bands were mentioned, as found in Saoli glen, and again in Doria end of Chatur-Doria hill. These consist of rocks extremely similar to sub-division *e* above described. In both of the abovementioned localities a thickness of limestone, properly so called, exists, for which no parallel is found among the group to which we have given the name of Lameta. But this limestone very frequently passes into an indurated marl with bands of purple and green calcareous mud, identical in aspect and texture with the characteristic rocks of the formation we are now describing. This resemblance is striking, and taken together with the fact that the Lameta beds occupy in the eastern part of our district, as the Mahadeva beds do in the western portion, a position intermediate between the upper Damudas and the trap, it suggests the *possible* identity of the two series in geological age.

General considerations.

The separation between the two, which we provisionally make, seems necessary in the present state of our knowledge of the rocks. From the Johilla valley to the Sher, the Lamèta beds are very constant in general character, and are at once recognized as belonging naturally to one group, whereas nothing like a passage of those beds seen near Karyia, into any of the Mahadeva beds to the west, exists. On the contrary, the rocks of that formation seen

nearest to this eastern part of their area, are the true grits and conglomerates of the group, and the beds lithologically like the Lamèta beds, are found only far away to the west.

No Fossils.

Little satisfactory fossil evidence has as yet been attained from either of these series; as has been stated, fossil wood only is known to exist in the Mahadeva rocks, and besides the silicified wood common in the Lamèta beds, we only know of some obscure bones from near Jubbulpur, and a doubtful fragment from Karyia. Some of the Jubbulpur fossils have turned out to be vertebræ, probably reptilian, but as yet undescribed.

§ 8. *The "Intertrappean" Series.*

Meaning attached to the term.

It has already been stated that the sedimentary rocks of this district up to the Lamèta beds inclusive, have nowhere been seen to rest on Trap, that is, as if they had been deposited there, but are, all of them, in many places covered, and frequently disturbed by Trappean rocks.

On the other hand the ossiferous (*) deposits of the Nerbudda valley the clays, gravelly and loose sandstones, there so largely developed, have no where been seen covered by basalt. If then we consider the basaltic or trappean period to be that geological era, during which the vast accumulations of the Deccan trap were formed, it seems safe to assert that it intervened between the consolidation of the highest of the Lamèta beds and the deposition of these ossiferous clays, &c.

During this basaltic period and in the intervals of these great discharges of lava, sedimentary deposits were formed at almost every part of the basaltic area, at least almost everywhere within that portion of it included in our map, and were again covered up by subsequent outbursts.

* The Lameta beds are, of course, not included here, although bones occur in them near Jubbulpore.

These deposits are therefore commonly found resting on one layer of trap, and covered by another: and hence the name first given to them by Dr. Carter of Bombay, of the "INTERTRAPPEAN LACUSTRINE FORMATION" (*a*) was derived.

The term has since been used with greater latitude and made to imply geological age as well as stratigraphical position, being often applied to beds which neither rest on, nor are covered by trap, provided that there be evidence to lead to the belief that they belong to the same age as those other beds which are literally intertrappean.

The "intertrappean" deposits as thus defined have long been known to geologists, and much labor has been devoted to the collection and to the study of the fossils with which they abound (see Introduction to this paper where reference is made to some of those researches.) The fossil evidence will not, however, occupy us at present; and our remarks will be confined to a consideration of the lithological character and position of the beds.

Lacustrine deposits.

So far then as we have to do with them, the beds of this intertrappean age are the remains of lacustrine deposits, formerly accumulated in probably detached basins, and under conditions slightly differing in different places.

This variety in the circumstances under which the beds were found is proved by the varied lithological characters which they now present.

Indurated siliceous variety.

Most of these, as would naturally be supposed from their mode of occurrence, have been much baked by the super-incumbent basalt, and they very commonly occur as a flinty or porcelain-like rock, with a conchoidal fracture, and of a dark blue grey, or sometimes a yellow brown color. Beds, and patches of beds, presenting these characters are found almost every where within the trap area, and they frequently contain great numbers of shells and many fragments of silicified wood.

(*a*) Journal, Bombay Asiatic Soc : Vol. V. p. 267, 1854.

Gorchutta Valley.

In the Sohagpur country a bed of this character has been followed for many miles round the base of the hills which enclose the Gorchutta valley (see map.) Its out-crop keeps at a fixed level a little above that of the valley itself, and may be followed in and round most of the little ravines.

Instance of two intertrappean beds.

In this place was noticed an example of a second, and lithologically different intertrappean bed separated from the first by a flow of trap. This upper bed is not nearly so extensive as the lower, and its out-crop was traced only for a short way along the hill side.* This lower or principal intertrappean bed of the Gorchutta valley varies little in thickness, and has nowhere been seen to exceed 4 or 5 feet. The extreme limits to which the same stratum may be distinctly traced, and positively seen to extend, are 20 or nearly 25 miles apart. In the adjoining part of the same district there have in many places been observed certain out-crops of a rock, lithologically identical with the above, and containing remains of apparently the same shells, occurring under conditions in every way similar to the Gorchutta beds, save only, that these out-crops are found at different levels. None of these detached patches were traced out with sufficient care to establish certainly that any one was actually vertically overlaid by any other of them, but the impression produced is that there can be no doubt that this is the case in many places.

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* It may here be remarked, that although this occurrence of different beds of the intertrappean rocks, one above the other, and separated by a layer of trap, is not frequently seen so very distinctly as to remove all possibility of error from the observation, yet it may nevertheless sometimes thus be found : the case referred to in the text is one example, and two very well marked instances occur near the station of Sagur.

These cases, here referred to, are exhibited with all the unequivocal clearness of a diagram, but in addition to this there abound, through the district, instances where the evidence, although certainly less clear, is still such as to afford a cumulative weight of proof quite irresistible.

It would then appear that during the period when often repeated outbursts of volcanic matter were accumulating layer upon layer the vast masses of basalt which now form the high table lands, and some of the lofty hills of this district,* lakes existed, sometimes of considerable size, in each of which these deposits of the same kind of sediment were accumulated† and which were all inhabited by Mollusca of the same species. In the cases mentioned above this sediment was almost exclusively a silicious band, which was subsequently baked by the overlying basalt into the porcelain or flint-like mass which we now find it.

Intertrappean rock sometimes not indurated

Sometimes however, though not frequently, a soft mud has been found lying between two layers of trap uninfluenced by the altering action of the molten lava, containing shells identical with those which occur in the hardened beds, and still remaining in the condition in which we must suppose these now altered beds originally to have been; and yet nothing was observed suggesting a cause why results so unlike should have been produced from conditions so similar.

Examples.

The locality from whence Dr. Spry first obtained specimens of *Physa Prinsepii*, near the church at Sagur, is a case of this unindurated intertrappean deposit. Another was observed near Kappa village in the Gondwarra hills, and a few others might be mentioned. In all of them, as indeed would be naturally expected, from the friable condition in which the bed is found, the outcrop is soon lost; all traces of it being obliterated by recent denudation and hidden by surface soil, &c.

Calcareous intertrappean beds.

Beds of every variety of composition may, of course, be highly indurated or may remain in a soft state as circumstances unconnected with their ingredients shall have determined, but all those hitherto spoken of may be considered as

* See Journal Bombay Asiatic Soc. Vol. V. page 614 for Dr. Carter's views on the subject.

† In this part of the country the beds at different levels are lithologically exactly similar; elsewhere very dissimilar rock is found in the continuation of the same bed.

for the most part silicious. Distinct in composition from these and almost as widely spread, we find beds more or less calcareous, often earthy or sandy, and frequently very like the marls of the Lameta group, with which they may readily be confounded. These, like the former, present all degrees of induration, and are found to occur in all respects as those silicious beds do.

The calcareous bands of the intertrappean rocks occur largely near Sagur, and have been noticed in the Sohagpur district in several places. From the Sagur parade-ground, along the foot of the hills to the north of the Indore road, a nearly continuous out-crop may be traced for miles. Again to the south of Sagur, near Narrainpur* a similar bed is found, resting on the Vindhyan sandstones, and covered by trap. Here the rock (itself sometimes a mass of minute Paludinæ) is hardened into a marble in one place, while a few feet off it is so friable as to crumble between the fingers. Besides the small shells, large specimens of Unio Deccanensis, of Physa Prinsepii and colossal vertebrate bones, are embedded in this calcareous bed. These bones were too much broken for identification. They have been supposed to have belonged to large Pachyderms, or possibly to cetacea. What has been said of the prevalent lithological characters of the intertrappean rocks is far from exhausting the subject: many other varieties might be mentioned: but it will perhaps be sufficient to furnish one example of what may be considered as a specimen of the exceptional developements of the intertrappean rocks. It is exposed in one of the glens of the Gorchutta valley, a few miles from the village of Singwarra.

Exceptional section. In descending order—

30 to 40 feet of sub-columnar Trap shewing well a concentric structure. The joints of the columns are very short and wide and each column presents the appearance of a pile of very much flattened spheres. This rests on

3 ft. to 6 inches of dove colored grey earthy limestone, containing many shells. This bed which varies (as stated) consider-

* Captain Nicolls' fossil locality.

ably in thickness, does not seem to have been even slightly influenced by the superincumbent basalt. It rests on

6 to 7 feet of a mass which is made up of irregular lenticular patches dying out and replacing each other, and which differ from each other as follows—

(*a*) A grey limestone somewhat like the bed above, but is more earthy, and contains fewer shells. Though less calcareous on the whole, it is traversed by many veins of pure carbonate of lime, which do not occur in the upper bed.

(*b*) A fine grained green loam with an incipient concretionary structure, containing a few threads of carbonate of lime, no shells.

(*c*) The last named variety passes into this one; the veins of lime become larger, and highly crystalline, until the mass is a crystalline limestone, with a few flakes and strings of the green earth; and these at last disappear. The limestone is a faint yellow or drab color, and very coarsely crystalline. The facets of the crystals have the pearly lustre of dolomite. (A bed similar to this is seen near Babga, on the Jubbulpur and Mandla road, and a mass not traceable to a bed was cut through in a well at Sagur.)

Beneath this comes trap, in a trough of which underlying flow all the above beds seem to have been deposited: their out-crop does not extend more than 200 feet in the line of section exposed by the stream; nor is there any reason to suppose that they ever extended much farther.

Many years ago Dr. Spry,(*) and subsequently to him Capt. Nicolls,(†) studied and described certain trunks of palm trees whose silicified remains are found embedded in the soft intertrappean mud beds near Sagur.

Many points of considerable interest are involved in the descriptions and

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(*b*) This is given on the authority of Dr. Carter, vide Jour. Bombay Asiatic Soc. Vol., V. page 614.

(*) Journal of Asiatic Soc, of Bengal Vol. II page 639.

(†) Journal Asiatic Soc. of Bombay, Vol. V. p. 614.

speculations published by both these geologists for which their papers may be referred to.

The trees are embedded in a layer of calcareous black earth, which formed the surface soil in which they grew: this soil rests on, and was made up of the disintegration of, a layer of basalt. It is covered over by another and similar layer of the same rock near where the trees occur. The ordinary fossil shells of the intertrappean beds are found in the continuation of the same intertrappean layer which contains the trees, both where the tree-bed is still soft black calcareous clay, and further on where it is a hard limestone. Large distorted specimens of Physa Prinsepii have been found in this bed.

The trees must have been thrown down or have fallen, and been silicified before the advent of the layer of basalt which now lies on them; and they could not have been transported by water from a distance and deposited here together. Thus they of course cannot be supposed to belong to an older formation, and to have been re-deposited in an intertrappean bed after fossilization during a geologically anterior period.(*a*)

These remarks on the intertrappean beds of our district must be considered as purely geological as distinguished from palæontological; and leave the fossil evidence untouched. This latter part of the subject does not seem to the writer to have obtained a developement which warrants any very satisfactory conclusions: whereas it is hoped that facts of observation may serve *pro tanto* some useful purposes to future observers.(*b*)

Since the above was written a short abstract of a paper "On the tertiary deposits associated with trap rocks in the East Indies" read by the Rev. S. Hislop before the Geological Society of London at their meeting of the 15th June 1859, has been received.

(*a*) *Vide* Contribution to Geology of Western India by Dr Carter, Bombay Asiatic Soc. Jour. Vol. V, p. 614.

(*b*) During the geological examination of the Nerbudda district, special attention being directed to the more detailed examination of the several groups of rocks described above, the time at the disposal of the geologists for the investigation of the intertrappean series was

The limits of the area under description at present do not permit us to follow Mr. Hislop in all his researches, which extend far beyond our district. But so far as his views relate to that district it seems needful to offer a few remarks.

Mr. Hislop states his belief that the amygdaloidal trap which underlies the "intertrappean" sedimentary rocks was liquid subsequently not only to the deposition of that rock, but also to the consolidation of the upper trap, both of these having apparently been broken up by it: still he thinks it probable that the lava in both positions belonged to the same eruption, the upper portion of it having cooled first. We would only repeat, that

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necessarily limited. Nor were there within the districts visited so many localities, where these "intertrappean" beds were visible, as there are in other parts of the country. The survey collections have, however, been enriched by many organic remains from these beds, presented by the Rev. S. Hislop of Nagpur, and altogether they include a fair series of shells &c. representative of the group. In the examination and description of these much progress had been made, and it was intended to have given here a brief diagnosis of all the species we possessed, together with figures &c. Meanwhile, however, Mr. Hislop himself having both sent, and taken with him, to England a large collection of these organic remains has devoted his attention to their description and has laid before the Geological Society of London the results, the abstract of which has reached us while this was passing through the press. In the Journal of that Society, the description &c. will appear at full. Mr. Hislop's collections being, probably, far better than those to which we have access, we have determined to withhold for the present, all specific descriptions of the latter, it being far better that a few weeks' delay should occur than that the same shells should be described under different names. We have therefore, placed all our drawings &c. at Mr. Hislop's disposal.

The condition in which these remains usually occur is particularly unfavorable for the accurate determination of species. In some few localities the shell itself has been preserved, but it is generally exceedingly difficult to extricate it, in consequence of the cherty and splintery character of the mass in which these remains are embedded. But in the majority of cases, little is found but a sharp silica cast, which, although sufficient to establish the identity of one specimen with another, affords no sufficient or reliable characters for detailed description.

As mentioned above, only some of the localities from which our collection contains shells have been visited by the officers of the Geological Survey. The most easterly of these was

within the larger area examined by us there is *not the slightest shadow of evidence* to bear out this supposition of the subsequent intrusion of the lower trap. In many cases the bed of the intertrappean sedimentary rock shows every gradation from a hard porcelanic flinty mass to soft clay, and in every case this gradation is distinctly from the hard mass in contact with the lower surface of the upper flow, to the soft and unaltered deposit in contact with the surface of the lower trap. It is obvious that precisely the opposite of this would be the fact, if Mr. Hislop's

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Goráhá a small village situated in the flat country beneath the Northern scarp of the Omur Kantak table land. The drainage of this plain falls into the Sone. The village of Goraha is itself placed on sandstone (of "lower Damuda" age) over which are strewed numerous blocks of altered intertrappean strata, derived from the beds *in situ* on the hills adjoining.

Near Mundla, further to the west, at a village called Pulsăgur, the intertrappean beds are seen in situ: and here are interesting from the gradation which they exhibit in the amount of alteration they have undergone. The upper portion is converted into a black cherty mass, from which it is exceedingly difficult to extract specimens, although shells (principally *Physa Prinsepii*) are by no means rare: while the lower portion of the bed is softer, of a brownish colour, and in parts earthy. In this portion the shells (chiefly *Lymnæa* and *Paludina Deccanensis*) are well preserved, and easily procured.

The rich localities in the Nagpur territory, are next, in position, as we proceed westward. All our specimens from these have been contributed by Rev. S. Hislop. These are Chikni, Taki, Telankheri, Phisdara, Karuni, Butara, and, further to the west, Ellichpur. These localities, or at least some of them, have also yielded numerous vegetable remains, which are of great interest; and which it is hoped, Mr. Hislop will succeed in having carefully examined and described.

Similar fossils occur at Gujri at the base of the Gharee ghat in the valley of the Nerbudda, and in a few places near Buowai (chiefly, if not entirely *Physa*).

A very important fact, if supported by further and more careful investigation, has been stated with regard to these deposits by Messrs. Schlagintweit, and repeated by Mr. Hislop. This is the occurrence in the same beds of "the unmistakeable freshwater *Physa Prinsepii*, with numerous true marine species" (*a*) near to Rajahmundry, on the Godavery. Mr. Hislop, who, however, has not had the opportunity of visiting the locality, bears out this statement. (*b*)

(*a*) Jour. Asiatic Soc. Bengal, 1857, p. 107.

(*b*) Proceedings Geol. Soc. London, June 15, 1859.

supposition were correct. In every case within our experience, the sedimentary beds have been deposited tranquilly on the *previously indurated* and *moreover previously denudated surface* of the trap rock; and in several cases a large portion of the material constituting these sedimentary beds is derived from the debris of the trap flows themselves.

Mr. Hislop further arrives at the conclusion that these "intertrappean" beds are of the same era as the so called "Diamond Sandstone."

It is, we think, to be regretted that this name should be retained, even provisionally, as indicative of a geological sub-division; inasmuch as it is almost certain that beds of very different ages have been described

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We do not desire to question the accuracy of these observations, although it does at first appear strange that such comparatively delicate freshwater shells as Physa shall be well preserved, associated with heavy and massive marine shells such as Cardita, Perna, Ostrea, Cytherea, Psammobia &c.

But we would certainly venture to suggest a careful examination of the localities. Among a collection of shells from this deposit near Rajahmundry, procured through the kindness of the Hon'ble Walter Elliot, of Madras, and *containing some thousand individuals representing about* 20 *species*, there is not a trace of a freshwater shell, and we think it just possible that the distinct deposits have been found in close superposition, and have been hastily taken as one and the same. That there should be a gradation from pure freshwater and lacustrine deposits on the west to estuary deposits towards the east is at the same time by no means improbable.

Up to the present time Mr. Hislop has published only a list of names of species from these intertrappean beds, in which he gives the following, *Melania*, (2), *Paludina*, (12), *Valvata*, (4), *Succinea* (1), *Lymnæa*, (5) *Physa*, (2), *Unio*, (6),—in all 32 species with two varieties. Our specimens would lead us to results somewhat different, and this difference is of considerable importance as bearing on the nature of the deposit, inasmuch as we are led to believe that several of our shells belong to different genera, and that they are land rather than freshwater shells. We give a list also, of what our collections contain, *Melania*, (1), *Paludina*, (6), *Valvata*, (3), *Lymnæa*, (7), *Physa*, (3), *Achatina*, (7), *Unio* (1) (?2), *Cyclas*, or *Pisidium*(1),—in all 30, with 2 or 3 varieties. These have all been named and described for some time but not published. For the reasons given above any detailed account of them is now withheld.

We would add here that we have for some time had very strong doubts that some of the shells derived from localities in the vicinity of Nagpur really belong to this "Intertrappean group at all. The general constancy in mineral character of these beds wherever

under this name. In one place (vide Memoirs of Geol. Survey of India, Vol. II, p. 65,) the rocks hitherto so called have proved to belong to very much older series. But disregarding the name for the present, Mr. Hislop states that he considers these uppermost beds under the trap to be of the same age as the sedimentary beds now included between the trap flows. The statement that "*paludinæ* along with much silicified wood" occur in these sandstone beds, is of much importance. Mr. Hislop, probably with much justice, refers these "Intertrappean" beds to the lower eocene age, pointing out the analogy with the remarkable fresh-water beds of Rilly in France.(*a*)

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they have been met with and their "intertrappean" position actually traced, is remarkable From this prevalent mineral character, the nature of some of these Nagpur deposits is very widely divergent. And taking into account the fact that these beds have not been actually traced into position, that their mineral character is remarkably similar to that of beds in the same immediate vicinity which contain fossils of a very much older geological series, I would suggest the consideration of whether some of these freshwater remains may not hereafter prove to be of much earlier date, and even to belong to about the epoch of the Wealden.

It is worthy of notice, that in Bengal, in the Rajmahal hills, there are intercalations of beds of clay and sand between trap flows, which beds, in that district, contain abundant remains of plants very beautifully preserved, but which have as yet yielded no trace of animal remains with the exception of a single elytron of a beetle, (Buprestidæ ?) The evidence of fossil plants is at best imperfect, but the whole group of these remains points to an upper Mesozoic Epoch, and there is a strong general resemblance to the Wealden flora of Europe, with at the same time, some very anomalous occurrences of forms, and even of genera, only hitherto known in rocks of much older date. The full details of these facts are now in preparation for the press. Can then, these intertrappean beds of Bengal represent the same epoch as some at least of the intertrappean beds of Western and Central India. And is it not possible that the beds at some of the localities mentioned above and which have

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(*a*) Mem. Geol. Soc. de France, Vol. III, 2 Ser. p. 257. The same eocene age was long since suggested as the most probable epoch for these upper, or as we have called them "Mahadeva" rocks.—Mem. Geol. Survey of India, Vol. I, p. 171. Indeed, the analogy of the "Intertrappean" beds of Central India with the beds at Rilly was, we believe, first pointed out to Mr. Hislop by the Survey.

We have before alluded to the opinion of Mr. Hislop, that these eocene sandstones have been "metamorphosed into gneiss, by the intrusion, apparently, of some deep seated plutonic rock, evidenced by veins of pegmatite." There is, in our area, nothing whatever analogous to this, and no evidence whatever of such plutonic action subsequent to the deposition of these beds; on the contrary these beds are everywhere remarkably undisturbed and horizontal.

The occurrence of silicified trunks of palm trees nearly entire and well preserved, in the neighbourhood of Sagur cantonments, has been long known. So long since as 1833, Dr. Spry(*a*) in a paper published in the

been all hitherto put together, as older tertiary, may in reality be of even pre-cretaceous date. But the discussion of the age of the Mahadeva group of our classification, of the Lameta and subtrappean beds of Jubbulpur as connected with the subtrappean rocks of the Nagpur district, can only be satisfactorily taken up after the intervening country has been examined. I have long since suggested (*b*) that the former were of the Eocene age, a view which Mr. Hislop has now adopted. But that the upper and "subtrappean" beds of the sandstones in Nagpur, are analogous to, or even approximately on the same geological horizon as the upper beds of the sandstones in other places, is not only not yet established, but, bearing in mind the immense amount of denudation which has occurred previously to the outbreak of the volcanic flows, and the fact that the lowermost of those flows rests indiscriminately on rocks of all ages in the district, the probability is rather that these "upper" beds should frequently prove of very different age. This remark is the more called for, because some strangely erroneous identifications have been based on this supposition that, granting the base of the Trappean rocks to be throughout of nearly, if not exactly, the same geological epoch, the age of the sedimentary beds immediately underlying them must equally, be in all places of one geological epoch. A supposition, it is needless to say, entirely without any proof.

To facilitate identification we add measurements and a few brief remarks on the specimens we have in the Survey collections.

MELANIA.

1. *Melania quadrilineata Sow.* Chikni—

(?2). A large specimen, possibly another species, from Pahar-Singha Nagpur, measures 0.47—0.23.

(*a*) Jour. Asiat. Soc. Bengal, Vol. II, p. 639.
(*b*) Memoirs of the Geol. Survey of India, Vol. I, p. 171.

Journal of the Asiatic Society of Bengal, described their mode of occurrence, and the position in which they lay.

These trees, now silicified, were stated to be found on a limestone bed, mixed up with the debris of trap rocks. He notices prominently the peculiar fact that these remains were silicified, while in a calcareous deposit, inferring from this that the bed on which they now lay could not have been the place of their growth; but at the same time forcibly argues against their having been transported from any distance; seeing that all the thin tendrils were still attached to the thicker parts of the

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PALUDINA.

1. *Paludina Phisdarensis* (n s.) globose, imperforate, of 5 whorls, and having much the general aspect of the recent *P. Melanostoma* 0·60—0·45—Casts, presented by Rev. S. Hislop.
2. *Paludina Deccanensis*,—Normal form as described by Sowerby from Nagpur and Gujri.
3. *Paludina decipiens* (n. s.) This little species is very common at Gwalior and Pulsāgur. A single specimen of a very similar shell has been received from Takli. A fine specimen from Pulsāgur of 5 whorls, measures 0.24—0.15.
4. *Paludina princeps* (n. s.) shell larger and more elevated than P. Phisdarensis, whorls —0.67—0.40. A few specimens obtained from near Gujri. ? Valvata.
5. *Paludina informis* (n s.) A small species rather variable in size. The whorls increase rapidly, but the largest specimens are imperfect.

   The largest specimen measures 0.24—0.15.
6. *Paludina* (*rubicundula*) (n. s.) elongate, imperforate, upper whorls in some cases decollated; whorls 7 (?) —0.52—0.27 from Takli.

VALVATA.

1. *Valvata Butarensis* (n. s.) This species is closely allied to Paludina Deccanensis, not uncommon at Butara; a large specimen of 6 whorls, measures 0.45—0.35.
2. *Valvata planorbis*, (n. s.) A very minute shell of depressed discoidal form, common at Gujri; also received from Butara: diam. 0.05
3. *Valvata minutissima* (n. s.) A globose turbinate species finely striated spirally; diam 0.04. Gujri.

LYMNÆA:

1. *Lymnæa subulata*. Sow. Common and widely diffused both in the Nerbudda and Nagpur. A fine specimen with 6 whorls, with the shell preserved, from near

roots, and that, therefore, there could have been little abrasion. He concludes, however, from the fact of a bed containing abundant remains of shells having been found in continuation of the bed in which these trees lay, that they could not have grown where they are now found.

Now the force of this latter argument rests solely on the erroneous impression under which Dr. Spry rested, that Physa Prinsepii and its associated shells, were marine, and the conclusion is therefore untenable: while at the same time the fact of these remains having undergone a siliceous fossilization in a calcareous bed is one to which many well known parallels might be adduced.

Goraha, measures 0.88—0.22. Other specimens are larger, some being very nearly 1 inch in length.

2. *Lymnæa fusiformis* (n. s.) A small species common at Goraha and Pulsāgur. A specimen of 4 whorls retaining the shell, from the latter place, measures 0.40—0.14. Some casts, however, measure as much as 0.65. The last whorl is nearly three times as long as all the rest.

3. *Lymnæa elegans* (n. s.) A smaller species than the above but otherwise not unlike it. It is common at Telankhéri and Pulsāgur. An adult specimen of four whorls from the former place, measures 0.44—0.15.

4. *Lymnæa Hislopiana* (*n. s.*) A small species common at Gorahā and Pulsāgur. A specimen from the latter place retaining the shell, of 4 whorls, measures 0.40—0.14.

5. *Lymnæa tumida* (*n. s.*). A small species of 3 whorls, common at Pulsāgur. A full sized specimen measures 0.34—0.16.

6. *Lymnæa infrequens* (n. s.) A single specimen only found; whorls rather tumid, 0.44—0.18. It comes nearest to *L. subulata*, but is little more than one third as large.

7. *Lymnæa obtusa* (n. s.) A well marked species from Pulsagur; whorls four, which increase rapidly, 0.54—0.20. The body whorl is three times as long as the others.

There are in addition to the above several, which in the absence of better specimens cannot safely be discriminated, but which appear to be distinct species.

PHYSA.

1. *Physa Prinsepii* Sow. This species varies greatly in form and size; yet the most extreme variations appear to be only varieties of the same species. It is the most

So far, therefore, as Dr. Spry's observations go, they are clearly in favor of the view that these trees grew on the spot where the remains of them are now found; that the bed in which they occur is only a continuation of the same limestone or calcareous band, the out-crop of which may be traced along the base of the trap hills in the neighbourhood. Capt. Nicolls, in a subsequent paper(*a*) takes exception to Dr. Spry's statement that these vegetable remains rest *on* limestone; but, from the general tenor of Dr. Spry's remarks, and from his description of the bed as soft, and made up of trap debris, it is highly probable that the word *on* was a mis-print for *in*. The bed, probably does not, at the spot where

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abundant and widely distributed species, which occurs in these beds. A fine specimen with the shell intact, from Ellichpur, of five whorls, measures 2.55—1.65.

2. *Physa Prinsepii*, var. (*elongata*). At Gujri a very marked variety occurs, with an elevated and elongated spire, and seven whorls. Making a trifling allowance for broken top, it measures 2.88—1.50.

3. *Physa Hislopiana* (n. s.) A small species very numerous at Gorahā. A specimen in black chert, of 4½ whorls, measures 0.40—0.23.

4. *Physa tumida* (n. s.) A more rounded species than the last, and also a little larger. It is very common at Pulsāgur; one specimen measures 0.45—0.30, but some occur one-third larger.

ACHATINA.

1. *Achatina Medlicottiana* (n. s.) Shell elongate, spire blunt. A single specimen sent from Butara, whorls 5,—0.36—0.15.

2. *Achatina Hislopiana* (n. s.) An elegant elongate shell from Gorahā; slender, whorls 7. 0.35—0.08. This perhaps belongs to the *Spiraxis* group of the Bulimi.

3. *Achatina conica* (n. s.) An elongate species common about Nagpur, whorls 6. 0.60—0.15.

4. *Achatina tumida* (n. s.) A pretty little species common at Telankheri; intermediate in form between Lymnæa Hislopiana and L. elegans. The separation of this from the genus Lymnæa is rather doubtful. A large specimen of 6 whorls, measures 0.50—0.15.

5. *Achatina pusilla* (n. s.) A minute species of 4 or 5 whorls, of which but a single specimen was found near Goraha—0.20—0.06.

(*a*) Jour. Bombay Asiat. Society, Vol. V, p. 614.

these stems are found, deserve the name of limestone; but it is calcareous, and, close by, passes into a limestone. Capt. Nicolls on the contrary throughout his notes, speaks of it as "black soil," "bole," "alluvium," leading to an erroneous conclusion that it was the ordinary surface soil of the district, whereas it is a portion of these "intertrappean" beds of which we have been above speaking.

Capt. Nicolls'(*a*) statements with regard to the measurements and

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6. *Achatina penchi* (n. s.) The affinities of this fossil are obscure. There are several varieties which so run into each other, that they cannot be separated, although they are probably specifically distinct. They occur abundantly at Telankheri. A lengthened specimen, of 7 whorls, measures 0.34—0.14—another of less elongated form, of 6 whorls 0.28—0.15.

7. *Achatina Eos* (n. s.) A more elongate form than the last and apparently a distinct species. A specimen of 9 whorls measuring 0.37—0.13.

UNIO.

1. *Unio Deccanensis.* Sow. This species does not occur at any of the localities visited by the officers of the Survey. The shell is stout, externally smooth, and devoid of either concentric or radiating lines. The internal layers, however, when the surface of the shell is abraded, exhibit strong furrows and ribs radiating from the umbones to the margin, which is thereby rendered crenulate. The peculiarity is well marked in a specimen from Katrumi, but traces of the same structure are seen in the perfect specimen from Ellichpur. A fine specimen measures 1.70—2.67. There is a marked variety (? different species,) much more quadrate, but in absence of better specimens, it cannot be discriminated.

CYCLAS (? PISIDIUM.)

1. *C. lens* (n. s.) Two specimens of a small bivalve, provisionally referred to this genus were found at Goraha. The largest has a breadth of 0.18

It is to be understood that the MS. specific names which have been given to these shells, and which are those under which they have been exhibited in the Museum, Calcutta, since July 1858, are simply used here for the sake of distinction. Mr. Hislop's detailed descriptions, when made public, will doubtless include all the varieties and his names will be retained.

I must add that the measurements, &c., which are in Inches and decimals, have been prepared by my colleague, Mr W. Theobald, Junr.—(T. OLDHAM, Oct. 1859.)

(*a*) Capt. Nicolls speaks of the flow of trap which he supposes to have overturned these trees, as being 4 feet 6 inches thick; and doubts that this would be sufficient to pro-

description of the tree stems are accurate and well given; but there do not appear to be equal grounds for admitting his conclusions as to the mode of fossilization. This, he argues, must have occurred after the trees had become recumbent; for if silicified previously, the fall would have shattered them to pieces, whereas in a length of 20 feet from the root there was only one interval of one and a half inch long, between the pieces longitudinally, while at the same time they had undergone considerable lateral displacement. This displacement also must have taken place after the trees had been lapidified, because the fractures are straight and even. He concludes from all "that the fossilization and displacement must both have occurred whilst the trap was unconsolidated, and must have been very speedy." The Editor of the Bombay Journal suggests with reference to this, that the fossilization and displacement need not both have occurred whilst the trap was still unconsolidated, inasmuch as an earthquake might have caused the displacement. It is difficult to see how any earth movement could have displaced the stems, and left no proof of the movement on the rocks enclosing them, which, on the supposition, were then (at the period of the earth movement) consolidated. Nor would it account for the trees being imbedded partially in the basalt. But Captain Nicolls further argues that the trees "could "not have been fossilized before they became recumbent; but that they "must have been upturned simultaneously with the outburst of trap, "and probably borne along with it for a short distance," as trap for a short distance underlies them.

We would remark that it by no means follows that this underlying trap is part of the same flow, as that which overlies, and partially encloses these stems; on the contrary, we believe it to be a portion of a long anterior flow.

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duce the effect. But the same may be traced continuously into the higher ground adjoining, where it attains a thickness of 60 to 100 feet and its present diminutive thickness of some five feet, where these stems are found, is apparently due solely to denudation.

Every analogy would lead us also to doubt the truth of any *speedy* silicification of these stems, in which the delicate vegetable tissues are all most thoroughly replaced by the silicious matter now composing them. And after a full and careful examination of the principal points where these occur in the neighbourhood of Sagur we feel satisfied that there is evidence, that there was here an extensive and tolerably level plain, broken in places by low hills of the Vindhyan sandstones; the general surface being formed partly of that rock, and partly of the lava flows, which had already filled up the chief hollows, and obliterated most of the original inequalities of the older surface. This plain was here and there covered by ponds and marshes, with patches of vegetable mould forming dry ground. The whole of the accumulations of detrital matter were calcareous, and we know that many species of land and fresh-water mollusca lived and died among them. The similar beds at Narainpur, also prove the co-existence of large animals, although their remains are now too imperfect to admit of a determination of their specific or even generic affinities.

The palm-trees, now found fossilized, grew in the soil, which in the condition of a black calcareous earthy bed we now find lying round their prostrate stems. They fell, (from whatever cause) and lay until their silicification was complete; a slight depression of the surface, or some local or accidental check of some drainage course, or any other similar and trivial cause, may have laid them under water. The process of silicification proceeded gradually but steadily, and after they had there in lapse of ages become lapidified, the next outburst of volcanic matters overwhelmed them, broke them, partially enveloped and bruised them until long subsequent denudation once more brought them to light. They may no doubt have been still further shattered by subsequent movements of the rocks, or even by the shock of the next superincumbent flow of basalt: but there is no necessity for resorting to such an idea to explain their present state and position.

§ 9. *The Trap Rocks.*

Trap area little explored.

The boundary of the great trap covered area to the south having been taken as a convenient limit to work up to, less time was devoted to an examination of the rocks included within this group, although offering many and most interesting peculiarities, than to others.

Trap of different age.

Although under the head of the Trap it is meant only to include the rocks of the great overflowing Basalt period, yet it may be well here to direct attention to some rocks very similar in lithological characters to parts of that basalt formation, though distinct from it in age. Trap is every where to be seen overlying, and trap dykes frequently disturb the Lameta beds; the basaltic epoque was in short certainly subsequent to the consolidation of the rocks of that series. But the "Mahadeva" conglomerate is in places almost altogether made up of trap detritus, and it seems natural to refer this to the degradation of the numerous dykes which traversed the Talcheer and lower Damuda beds, prior to the formation of the Mahadeva Rocks. The lowest beds of the Talcheer group however themselves contain fragments of trap, (see *Fig.* 5, p. 152). In the Rawundeo section already figured and described, the "Boulder Bed" is seen resting unconformably on some beds of crystallised schists where these are traversed by a dyke (which does not pass into the bed above) and one of the Boulders in this bed is a fragment in which a piece of the dyke wall remains adhering to the greenstone.

Proof of this.

Three Periods of trap intrusion.

We thus have good evidence of three periods of disturbance, when igneous rocks were intruded among the sedimentary deposits, 1st, one prior to the oldest Talcheer, 2nd, one subsequent to the Lower Damudas and prior to the Mahadevas, and 3rd, the great Basaltic period when all the overlying trap of this country was poured out over the surface.

No characteristic either lithological or mineralogical seems definitely to belong to the traps of either of the first two periods, which cannot, as far as I am aware, be paralleled in the third. And it will consequently be readily understood that it is only in very exceptional cases that the observer can be quite sure of any individual dyke being more ancient than the period of the most recent intrusion. The great dyke above Bhera Ghat, for instance, may belong to any of the three periods, as it is seen in contact only with the most ancient rocks. This is a remarkably fine dyke, and cuts across the course of the Nerbudda, sending off a branch beautifully seen as it disappears into the face of a cliff of white marble. But the course of the river through these *Marble Rocks* is probably itself that of an ancient trap dyke, from which the greenstone has been removed and the walls of which now stand as vertical cliffs of white marble between which the Nerbudda flows (see above *Figs.* 2 and 3, pages 135, 136). This is suggested by a comparison of the face of these cliffs with the walls of the Bhera-ghat large dyke, where the basalt still in part remains to show the origin of the fissure. (*a*)

Example, Bhera Ghât.

Confining our attention for the present to the tabular basalt, or the most recent trappean period, the most striking feature which it presents in our district, is the great regularity of the terraces formed by its layers. No where can this habit of Trap rocks be better seen than in parts of the Gondwarra range; the layers seem absolutely horizontal and of uniform thickness on the great scale. The aspect of the country round the old fort of Saoligurh is very characteristic of the physical features ordinarily developed in the trap-area, and especially of this terraced

Most recent Trap.

Aspect of.

Saoligurh.

(*a*) Sir C. Lyell quotes from McCulloch's description of Strathaird in Skye what seems to be a similar case. Manual of Geology, fifth edition, page 481.

arrangement, so well known as a peculiarity of these rocks every where.

The ground rises from the lowest levels in terraces, which correspond in height on the different hills, themselves all flat-topped save only the highest, where frequently a little boss of the last trap flow has been left by the denuding agents.

Chaneli and Richera country.

Far to the east again the trap becomes the prevailing rock of the country (see map) and the same features are developed. The new road from Chindwarra station to Nursingpur, passes over this trap country, and its course lies near the foot of Chaneli hill, one of the highest of the country. From its summit a commanding view is obtained; Deodungri hill, 20 miles to the west, Korekera hill, a greater distance still to the north-west, and Richera hill to the north, with many minor eminences, irregular ridges, and branching spurs, form a very striking landscape, in every portion of which the terraced outline of the trap rocks is distinctly marked.

The flows.

When examined in detail, this structure is seen to be due to distinct flows. Descending from Chaneli, or any other of the principal hills, a section across several of these flows is obtained, and each one may generally be distinguished from that above, and that below it, by some well defined mineral characters; but these characters are seldom found constant in any one bed or flow for any considerable horizontal distance if we follow them in that direction.

Lithology of the trap.

The most common varieties, lithologically and mineralogically considered are as follows:—

(*a*) Granular sub-crystalline diorite often porphyritic, with crystals of felspar.

(*b*) A hard heavy very ferruginous basaltic trap.

(*c*) A pale green crumbling earthy rock.

This last (*c*) is specially characterized by an exfoliating (or onion-like) structure, also frequently seen in (*b*) but never in (*a*). (*b*) and (*c*)

are frequently very vesicular. Besides agate, which is the most common occupant of the cavities, Heulandite is very common; immense masses of this mineral sometimes occurring, as at Saoligurh, and again near the base of Richera on the west side. The cavities which have been filled with it are very frequently lined with soft green earth.

Accidental minerals.

Cavities so lined often contain fine small crystals of quartz, which seldom fill the cavity completely, but are themselves as it were a second or inner lining. Frequently the vescicles of the trap are filled with this green earth unaccompanied by any other mineral, in which case they are generally quite spherical, of very uniform size (about $\frac{1}{8}$th inch) and regularly dispersed throughout the mass. Fine crystals of calcspar occur in the trap (*c*) near Kappa village, on the Nursingpur and Chindwarra road, and in many other places. Natrolite is also not uncommon, and Thomsonite occurs at the west foot of Deodungri hill. These last minerals have been found also in other varieties of the trap besides the one referred to (*c*). As has been already stated none of these lithological peculiarities nor the presence of any of these minerals, can be used to identify different parts of the same layer of the trap. On the contrary all the lithological characters and many of the minerals may be found in what are certainly parts of the same flow (although this is seldom the case) within a short distance.

The third variety we have mentioned (*c*) often appears to be the result of the decomposition of the harder and more solid (*b*) or even of (*a*).

Columnar structure is common in the dense trap (*b*). Hexagonal and pentagonal columns have been measured with a diameter of 22 inches, in the hill east of Buddi village. And near Burardo village a very peculiar minute columnar structure was noticed; the columns are triangular, and the sides measure less than half an inch across, giving the mass a fibrous look; nor do these columns appear regularly jointed in their length; a piece was obtained 19

Columnar structure.

inches long, but they break mostly into short fragments without showing regular articulation.

Col. Sykes on the Deccan Trap.

The trap area of our map may be considered as forming a continuation of the great Deccan trap, described in 1833 by Col. Sykes in the Transactions of the Geological Society of London, (*a*) and many of the remarks he there makes are applicable to this part of the country. He mentions the pseudo-bedded character as very prominently marked by terraces on all the hills save where the many strata "instead of being arranged in steps form a continuous "wall. At the Ahopeh pass at the source of the Goreh river, the wall "or scarp is fully 1,500 feet high: indeed on the north-west face of the "hill fort of Hurreechundurghur, the escarpment can scarcely be less "than double that height. On the other hand the steps are some-"times effaced, and a hill has a rapid slope. This originates in a "succession of beds of the softer amygdaloids without any basaltic in-"terstratification: their superior angles disintegrate and a slope results. "But most usually three or four beds of amygdaloid are found be-"tween two strata of compact basalt. The former disintegrate leaving a "slope, which is not unfrequently covered with forest trees forming a "picturesque belt. The basaltic scarp remains entire, or it may be "partially buried by the debris from the amygdaloids above, but its "great thickness usually preserves it from obliteration, and it rises "from the wood below with majestic effect; its black front being "finely contrasted with the rich and lively green of its sylvan asso-"ciate."(*b*)

Korekera escarpment.

In the north face of the range at the place where it is called Korekera hill, (see map) there is a scarp altogether about 1,200 feet high, of which 800 feet is clear precipice, and this is the nearest approach to the gigantic escarpments of

(*a*) Trans. Geol. Soc., London, 2nd Ser., Vol. IV, p. 409.—(*b*) *Ibid.* p. 414.

which Col. Sykes speaks in the Deccan; but even in our area, several such escarpments occur, and the description contained in the above passage is (with *this* reservation, of less height in the hills) applicable to much of the trap country of our map. With regard to the mineral structure and composition of the trap flows the same author found that "it varied exceedingly in "short distances even in the same stratum."—"The basalt in one "continuous bed may pass several times from close-grained compact "and almost black, to grey amygdaloidal, and externally decompos-"ing."

Lithology of Trap.

Col. Sykes states, that he, as well as all previous observers, had failed to detect satisfactory evidence of craters, or even of their probable sites; nor have we, in our portion of the trap-area, been more successful. No apparent volcanic centre can be pointed to, from which any, or several of the many flows have probably proceeded. The only approach as yet made to the solution of this problem may be found in the unequal distribution of the evidence of the intensity of igneous action in certain areas, this intensity being estimated both from its mechanical and chemical point of view. For we can show that in some places the intrusion of the trap has been accompanied by a minimum of disturbance, that it has filled cracks in the sedimentary rocks, and overflowed their beds, without affecting their texture (chemically) or being itself acted on by their vicinity. Whereas in others, the reverse of all this is the case; beds have been shattered; fragments of them enclosed; and both the sandstones and the traps much altered at their junctions.

Centres of eruption.

Approximation to the discovery of these.

Perhaps careful and widely extended observations of these phenomena might guide into the discovery of volcanic centres, but, as already stated, the trap area having only been cursorily examined, we have little to advance on a subject eminently requiring great caution both in observing and in drawing conclu-

Closer examination requisite.

sions from observations. Moreover, it is evident, that this method can be used only where the sedimentary rocks appear, that is at the edge of the trap area—a position which is *a priori* improbable to have been that of any of the ancient centres of eruption.

Continuous beds or flows.

No geologist can pass through any part of this trap-area without being struck by the persistence of the layers of basalt, in thickness and horizontality, over great distances.

"The question of the manner of the formation of the horizontal beds "of trap is very interesting. It will be said they were ejected under the "pressure of an incumbent ocean. If such had been the case, where "are the marine remains? and would there not have been sediment-"ary deposits upon them? Moreover, if viewed as coulées from craters, "would not the beds have thinned out, instead of preserving the pa-"rallelism of their superior and inferior planes?" (Col. Sykes as quoted above.)

Unaccounted for.

The difficulties stated by Col. Sykes in this passage must in great part remain for the present unsolved. Those inter-trappean beds discovered since it was written clearly show that the basaltic flows were not sub-marine; but I am not aware that any satisfactory explanation of the extraordinary parallelism of the upper and lower surfaces of the trap flows has been suggested, or any cause assigned why those flows are found so uniform in their thickness at points far removed from each other.

DYKES.—Among the numerous trap dykes found throughout this district many of the well known phenomena of the action, and *habits*, of intrusive rocks may be well studied. In most of the great dykes the well known fact of a system of joints at right angles to their sides, may be seen; it amounts often to columnar structure, the columns lying flat when the dyke is vertical, and being inclined to the horizon in a direction at right angles

Jointing at dyke wall.

to its underlie where it has any dip or *hade.* And this structure is always obscured, or quite effaced, near the sides of the dyke, where the rock becomes flaky and splits into laminæ more or less thin and regular and parallel to the dyke wall.

Alteration of dyke.

Although as a rule, the intrusive rock does not generally much *alter* the beds among which it has come, yet itself is very often influenced near the junction, apparently by the proximity of the mass with which it has come into contact.

Soplye Dyke.

Fig. 13 *b.*, p. 225, is a diagram representation of a good case of this. A fine dyke of greenstone-porphyry exposed in a stream, near Soplye village, cuts the beds of the Lower Damuda Sandstone. The rock of the dyke is highly crystalline and porphyritic along its centre, but compact and earthy near its sides, and has the structure of sub-vitreous obsidian at the plane of absolute contact with the bedded rock. At a distance of about 3 inches from the sandstones the porphyritic structure is generally clearly developed, though the change mentioned above is quite gradual, and the passage from the glassy film at the dyke wall to the crystalline rock at its centre, is not everywhere equally rapid. Many small veins start out from the main dyke, and two of these, well seen near the place represented in our sketch, are in part of their course no more than an inch in width, yet along the centre of these little veins, not only is the crystalline structure preserved, but even the porphyritic, and their sides imitate the compact and the pitchy appearance of the corresponding portions of the parent dyke, of which they are in these respects perfect miniatures. It would be imagined that every portion of these small veins must have cooled more rapidly than that portion of the great dyke half an inch from its sides; still, in the latter case, the rock is invariably compact, and earthy, whereas in the former we find crystals—facts not accounted for by any hypothesis on the subject of crystallization from fusion with which I am acquainted.

When the trap has been forced among those soft beds, some of which may be found in all the sandstone group above described the dykes formed seldom have their walls so rectilinear as when they cut through the sandstone beds.

Dykes among soft beds irregular.

Fig. 13. Sketches shewing different forms of Intrusive dykes.

Fig. 13,*a*. Fig. 13,*b*.

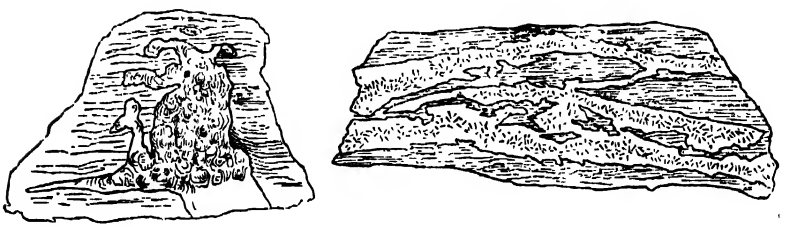


Fig. 13,*a*, represents a typical case of the habits of the dykes intruded among the soft beds, and is a sketch of one exposed in the Machiriva, near Murrye village. And *Fig.* 13,*b*. shows a corresponding example of the angular and rectilinear form of outline of those which occur among the sandstones.

Murrye Dyke in mud bed.

In *Fig.* 13,*a*, the characteristic curved outline and numerous offshoots are well shewn. Many cases occur in which these features are far more strikingly exhibited.

Soplye Dyke in Sandstone.

At the base of Latideo hill a fine dyke of porphyritic greenstone cuts through the green mud beds of the Talcheer group, and is exposed in section on the vertical face of a cliff. On this surface, and within the space of a few square feet of it, thirteen small irregularly shaped patches of Trap were counted, and it was at first supposed that they were fragments of the greenstone embedded in the sedimentary rock. On examination, however, it was found that each one was connected with the main dyke. By digging away the surrounding Talcheer rock, it became apparent that some of the patches, though showing a circular outline on the section surface,

Dyke in Latideo hill.

soon spread into lenticular layers, but several stood out, when fully exposed, like the branches of a tree, irregular solid cylinders of greenstone. These were apparently intruded into *crevices* formed in the green mud bed, as it yielded to the force from below and shrunk from the heat of the intrusive rock.

Dyke in the Mopani Section.

A good case of the way in which minor offshoots strike out from the principal mass of a dyke, is seen in the Sitariva River in Mopani, and occurs in connection with one of the dykes shown in the section represented in *Fig.* 8, page 169. The river has excavated its channel in a direction at right angles to that of the dyke, and exposed a good section of it in the bank. The dyke intruded apparently from below, did not reach as high as the level of the present surface of the ground, a continuous layer of the sedimentary rock lies over the ridge of the dyke, but this is penetrated by numerous small veins of various shapes and sizes, which the dyke below had projected upwards.

Offshoot veins.

Another and somewhat remarkable instance occurs on the course of this same dyke, and not far from the locality mentioned. The dyke, and the original rock are well exposed in plan. A small vein, never more than 2½ inches wide, starts out from the side of the main dyke, from which it is never more than 4 inches distant, and parallel to the side of which it runs for 21½ feet, when it again returns to, and is lost in the parent mass, thus enclosing a narrow strip of the sedimentary rock, 21½ feet long, and 4 inches wide, and the line followed by the little vein is quite independent of the bedding of the sandstone, here a green earthy rock and nearly horizontal.

Remarkable case.

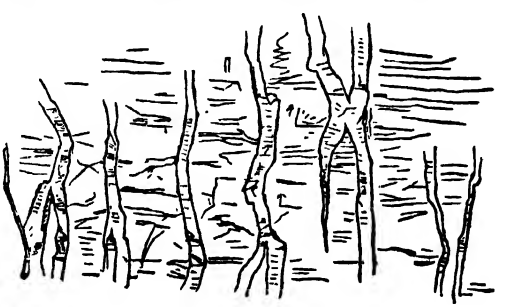
Much might be said on the subject of the trap dykes of this district. They are, as may be seen from our map, very numerous, and many of them from peculiarities in weathering, form striking and picturesque features in the landscape. But

Dyke in the upper Tawa Valley.

I shall conclude by mentioning one which may be traced for miles along the upper Tawa Valley. Where it crosses the wide plain, its course is marked by a range of little hills, which zig-zag curiously over the low ground; each one of these little hills is irregularly oblong in shape, and seldom more than 100 yards long; or more properly, breaks occur in the continuity of the range at these short intervals, and at every break a change in its direction occurs. The hillocks are not widely separated, each rising almost from the foot of its neighbour, but two consecutive hillocks are sometimes nearly at right angles to each other, though generally only slightly oblique in direction. Standing on one of the high hills which command an extensive view over the valley, this dyke looks like a great chain-cable laid in a straight line on the ground, but whose links, from its not being drawn tight, lie irregularly zig-zaged, and do not individually keep parallel to the general direction of the whole.

Fig. 14, represents trap dykes seen near Hindia on the Nerbudda and is typical of the habit of the intrusive rock when seen cutting through jointed masses.

Fig. 14. Trap dykes, near Hindia, on Nerbudda River.



CHAPTER III.—FAULTS AND DISTURBANCES.

In the commencement of this report a sketch of the general aspect of the Nerbudda Valley was given, or rather of that portion of it, which is included in our map. The remarkable physical features now to be more fully described, characterize with more or less distinctness, the band of country stretching from the Gulf of Cambay on the west, to the Ganges valley on the east, and including the Sone as well as the Nerbudda River. Most maps of British India show a marked range, called the Vindhyan Range, running along this line; Mandoo stands near the western extremity of it, as generally shewn on the published maps, and Rotasgur at the eastern end. In reality, as before stated, no such range exists; there is a well defined *escarpment* facing the south, but instead of being a true hill range the slope of the ground from the summit towards the north is very gradual, and slight. This line of escarpment joins the north side of the valleys of the Nerbudda and of the Sone; it deviates little from a straight line, when considered as a whole, and even within shorter limits, its rectilinear direction is very remarkable. Running parallel to this line is a much less regular range, very different in general aspect, formed, as has been stated, of other rocks, and lying on the south side of the Nerbudda valley, within our area. Beyond the district surveyed, a very similar arrangement is known to form a continuation of the range along the banks of the Sone, the south side of whose valley has been found, (in part of its course at least) to be formed, like that of the Nerbudda, of rocks different from those of the Vindhyan escarpment.

The Vindhyan range.

The Range of the more recent Sandstone.

Any geologist who examines the accompanying map, Pl. I., will not fail to be struck with the very marked manner in which the different geological boundaries coincide with the physical features of the country. It is indeed generally the case that the experienced observer will

readily detect in any landscape the differences of outline presented by different rocks, and will sometimes be able roughly to trace geological boundaries to some limited extent, when he obtains a wide view over even a new district. In the district included on our map however, this is very remarkably the case. Perhaps, as regards the peculiarities of the landscape, one of the best examples of this is furnished by the contrasts afforded by the Mahadeva Sandstone to the Damuda and Talcheer flags and shales. A person standing on one of the crumbling walls of Asseer fort (see map) and taking a panoramic view will, if he looks north east, see the great masses of the Puchmurri hills forming the most striking object within the range of his vision, with their grand slopes, and sheer precipices of rock, facing south. The long line of the prolongation of that escarpment will bound his view as he turns north and will be lost in the distance towards the north west. Between that escarpment and the observer, several other minor ranges will be visible running parallel to it, and all having a precipitous face towards the south. On the prolongation of one of these he will find himself standing, and still another may be traced to the south nearly rivalling in height the Puchmurri range, and, as thus seen from the north, very steep though only here and there absolutely precipitous. Turning towards the west he will look across the wide plain of the Tawa, bounded on the north, as has been stated, by the prolongation of the Puchmurri range, and on the east by the terminations of those parallel, and minor ranges, on one of which Asseer fort was built. Opposite to him stand two high hills, apparently the terminations, in that direction, of ranges like those around him. The more southward of these is Bowerghur, and that to the north of it Jamghur, both crowned by old forts like that from which he is looking. But he will be at once struck by the difference of outline of these two hills: the former, as well as the lower summits of the range

Coincidence of physical feature with geological Boundary.

Contrasted outline of different rocks.

Seen from Asseergurh.

in which it stands, has a jagged, broken outline which contrasts strangely with the tabular arrangement and vertical sides of the latter. Even at this distance, it will be evident to him that Bowerghur is formed of the crystalline rocks, and Jamghur of the massive sandstones of the Mahadeva group.

Jamghur and Bowerghur.

Round from this to the south, pointed peaks and saddlebacked ridges, mark the continuation in that direction of the same class of rocks, nor can the observer doubt but that the flags and shales which are seen in the glens by which he approached Asseer fort, underlie the hill on which it is built, spread over the wide valley on the west, and underlie all the other tabular masses of sandstone around him. But again, consulting the map and observing the coincidence visible on it of the geological boundaries, with the physical features, the great Vindhyan escarpment is certainly the most striking example. The manner in which the boundary of the crystalline rocks runs along the base of the range south of the valley, from Lokurtullye (east) to near Jubbulpur, is only less remarkable. The generally rectilinear character of some of the geological boundaries will also be remarked: both of the above mentioned boundaries offer examples of this, as does that between the crystalline rocks and the upper Damuda rocks to the north east of Jubbulpur. Again, the southern boundary of the Talcheer and lower Damuda rocks of the hill country, North of Betul and Chindwarra, is a case in point.

Vindhyan Boundary.

Geological boundaries straight lines.

Considerations connected with these facts will suggest to the geologist even from an inspection of the map, the probability of these rectilinear boundary lines being also lines of fault, and this, as has been already more than once insisted on, is in reality found to be the case.

Conclusion suggested.

If we commence our examination of the north boundary of the Mahadeva rock in the western extremity of our larger map, Pl. I, near

Lokurtullye, and thence proceed eastwards along it, we here also find the rectilinear direction so closely followed as to constitute a striking geological fact. Much however of this part of the boundary between Lokurtullye and Patroda is not faulted. In several places it is so, and in these, evidence of the existence of the fault may be clearly observed, and near Patroda the fault itself is well seen. South of that village, the Hosungabad and Betul road passes close under two high pointed hills which are formed of nearly vertical beds of schistoze quartzite. From the summit of these peaks, the flat topped hills of the Mahadeva sandstone and conglomerate are seen to abut against, or to form as it were a continuation of the mass of these peaks themselves, and if from the junction of the two rocks at the higher level, the observer descend into the glen to the west, he will find at every step ample evidence of the fault.

The Faulted Mahadeva Boundary.

Seen S. of Patroda.

At Bagra again, where the Tawa issues from the hills into the plain beyond, some of the outer hills of the range are formed of the schist rocks, while the inner hills, as well as the bottom of the glen itself are of sandstone, and just below the fort, in the river bank, the fault may be seen, here bringing the crystalline limestone of the schists opposite the newer rocks. Similar cases may be found along the Mahadeva boundary from hence to the east, the sandstones are sometimes faulted against, and sometimes rest on the crystalline rocks.

Again at Bagra.

Futtypur, a large fortified village about half way between Nursingpur and Hosungabad (see map) stands in a gorge of this outer range through which a stream escapes from the hilly country to the south into the Nerbudda valley. Five or six miles to the south east of the village, the hill Chatur, already mentioned, rises to a considerable height and is formed of the conglomerates, sandstones, and limestones of the Mahadevas. If one descends from its summit, to

Again near Futtypur

the south, these rocks are found down to the base of the hill, and rest on the lower Damuda beds of the valley, but descending from Chatur towards the north, a long spur, which runs out in that direction, will be found to end abruptly in a small, half detached hill, where the following section is exposed.

Fig. 15. Section seen near Chatur Hill.

(*a*) Conglomerate beds of the Mahadeva group; horizontal. (*b*) Quartzite and limestone, metamorphic; vertical.

The detached hill, itself as high as the end of the spur, is formed of the nearly vertical beds of the quartzite and limestone of the schist series, while in the latter, the horizontal conglomerate beds of the Mahadevas, are brought close opposite to these in the side of the little gorge which separates the two. The gorge itself being higher than the valley beyond, the faulted boundary between the two rocks is clearly seen by walking down it.

Again in Barha glen.

East of this, again, the glen of the Barha Nuddi, (opposite to the opening of which Kuluri village stands in the plain (see map) affords a section illustrating the faulted nature of the Mahadeva boundary. Here the massive beds of sandstone and conglomerate (which farther on form Nimbnagur Hill) are seen to be contorted on the large scale; they are bent up at the end next the boundary, and are cut off straight in a vertical scarp.

Again in Mopani Section.

Farther to the east, the valley of the Sitariva River, in which the Mopani Coal beds are exposed, (see *Fig.* 8 p. 169,) affords some instructive sections, throwing light on the nature of the boundary of the Mahadeva. The river runs northwards from the hilly country into the Nerbudda valley, through a glen in the upper part of which the Mahadeva conglomerate beds are seen to

rest unconformably on the disturbed strata, of the coal bearing lower Damudas. Farther down the valley, all the overlying Mahadevas have been removed by denudation, and a good section of the beds of the lower formation is exposed. As was stated when this section was described, these are cut off by a fault, about two hundred yards farther down; the amount of the fault cannot be ascertained, but it is a down-throw to the south, and north of it we find the representatives of the lowest part of the series, namely the green mud and "Boulder bed" of the Takcheer group. Now it is found that this fault, whose existence is thus proved independently of the Mahadeva rocks, is on the prolongation of the line of their boundary, and that it has its down-throw, in the direction corresponding to the direction of the down-throw of their boundary fault.

Varied character of the Mahadeva Rocks at their boundary.

It has already been noticed that the present boundary of the Mahadevas coincides to a great extent with the ancient shore of the basin in which those rocks were deposited, and the presence and mode of occurrence of the conglomerates of the series along the line of boundary has been pointed out as corroborating this view.

Old shore line.

The original shore and the present boundary, do not however by any means thus coincide always, for the fine grained sandstone, and the limestones of the group, which were probably not shore-deposits, sometimes appear at the present limit of the formation, on the outer edge of the hills, and thus we find that the boundary line of the Mahadevas keeps its rectilinear direction independently of the nature of the beds which it cuts off.

Various rocks along the Mahadeva boundary.

Nor, on the other hand, does it seem to be in any way connected with the stratigraphical features of the crystalline rocks, which are found along it, faulted against, or supporting the Mahadeva beds, for all the varieties of the schists may be seen abutting in succession against it; the soft, and the hard, the calcareous, and the siliceous, and the intrusive granite asso-

ciated with these. It cuts them all, and brings each in turn opposite to the conglomerate and sandstone of the Mahadevas.

Dilheri section.

Proceeding along this boundary to the east from Mopani on the Sitariva, we come to the village of Dilheri (see map) near which a section may be examined, and again to that described near Futtipur. Here, however, we have an excellent example of the two-fold nature of the Mahadeva boundary.

Fig. 15. Sections seen near Dilheri and Futtipur.

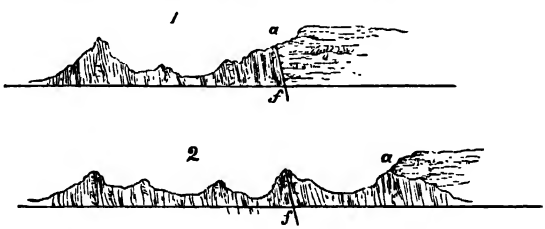


Fig. 15 represents two parallel spurs which stretch down towards the north from the range behind Dilheri, they are in the diagram placed parallel to each other, as they occur in nature, and are represented in section. The fault, (*f*) which in one brings the Mahadeva beds (*a*) against the crystalline rocks, in the other affects only the latter; and in this second spur the natural shore boundary of the Mahadeva rocks is seen. The village of Dilheri stands in a gorge of the lower part of the range. If from it we ascend the first mentioned spur, we find the crystalline rocks up to about three hundred feet above the valley, where (at the point *a*.) the beds of the Mahadeva sandstone are reached. If we descend from this point down the side of the spur, the junction of the schists with the sandstone will be well seen. Its line on the hill side corresponds to a nearly vertical plane, and at the bottom of the glen the sandstone is still found abutting against, and not resting on the schists; whereas in the other spur the Mahadevas, found at about the same height above

1st Spur.

2nd Spur.

the valley, but, farther to the south (at *a.* see diagram *Fig.* 15,2) may, by descending along the side of that spur, be seen to rest on the edges of the schist beds, as represented, and not faulted against them, as in the former case. This second spur now slopes down to the north, in the place where a head-land of the ancient shore formerly stood out, towards the south, into the waters in which the Mahadeva sandstones were being accumulated, and thus the line of fault, which has for the most part determined the boundary of those rocks, passed north of the old shore in this place.

Hinhotia section.

Near Hinhotia (12 miles S. of Nursingpur, see map) the Mahadeva sandstones may be again seen both faulted against, and resting on the schists and the granite; farther to the east, near Gungye, the fault may be again studied, and is again seen near Butchye.

Sehora Section.

The Sher Nuddi exposes, close to Sehora village, a section in which a fault is clearly seen (see map and section No. 1), here the beds of the upper Damuda series are brought against the crystalline limestone. But the fault is in the prolongation of the fault-line we have been considering, and which has up to here, formed the north boundary of the Mahadevas.

Lameta beds take the position of the Mahadeva proper.

Farther to the east, the great sandstone and conglomerates of that group are either absent altogether or hidden under the trap. But at the base of the hills, which here form the south side of the Nerbudda valley, are seen, under the trap, beds of the Lamèta series, while the valley itself is still formed of the vertical schists mostly covered by the ossiferous sands, clays, and alluvial black soil. The prolongation of the line of the fault we have been considering is still, however, marked by evidence of disturbance, precisely analogous to what we have detected along its course.

Near the villages of Gogri and Lameta (see map) a hill called Bowerghur* rises to a height of 400 to 500 feet above the valley, and is formed of schistose quartzite principally. It is separated from the general range of the Trap hills by a narrow gorge of which *Fig.* 16 is a section diagram.

Bowerghur Hill Section.

Fig. 16. Section at Bowerghur Hill.

In the bottom of the gorge the vertically bedded schists (*c*) are seen in contact with the horizontal beds of the calcareous sandstones of the Lamèta group, (*b*) and while the steep sides of the glen rise on either hand, one of these sides is formed of the former, and one of them of the latter rock. The trap (*a*) covers the Lamèta beds here as well as farther to the east, where they, and the upper Damuda beds, are both seen again faulted against and resting on the schists at Lamèta Ghât on the Nerbudda.

To the north east from Jubbulpur, this boundary, as may be seen from the map, is prolonged in a nearly straight line, and it must be considered as part of the same fault line as that which we have been describing. In this part of its course we have on one side of it the upper Damuda, Lamèta, and Trap rocks, and on the other the crystalline rocks.

Continuation of the fault boundary.

The faulted character of the boundary may be studied near the villages of Bùndi and Falgon (see map) and again near Sakri. From the latter village it runs along a narrow glen, up which the path from Sakri to Patra passes. On one side of the glen the calcareous sandstones topped by trap are seen, and close opposite them on the other, the syenite. And thus on in this direction, the boundary holds its course in a straight line, and has been traced as far as the Mahanuddi, where that river forms the limit of the territories belonging to the Rajah of Rewah.

* Not to be mistaken for a hill of the same name far to the W. and already mentioned.

The Lower Damuda and Talcheer Boundary.—If we now return once more to the western portion of our map, and carefully examine the line of country we have just described, it will be apparent that the north boundary of the lower Damuda and Talcheer was over-lapped by the Mahadevas, some beds of which group were deposited upon the crystalline rocks beyond the limits of the lower Damuda group in this direction; also that the present boundary of the Mahadevas (as determined by the fault) passed to the north of the northern boundary of the lower Damudas, for the most part at least; the only observed exception being that found in the Sitariva section above described, (see *Fig.* 8, p. 169,) where the lower rocks extend considerably beyond the Mahadeva boundary line, and stretch well out into the Nerbudda valley.

Mahadevas over-lap the lower Damuda and Talcheer Rocks.

In the next place we are led to conclude that the old lower Damuda and Talcheer boundary is itself a faulted one, because although little of it can be examined, yet in every place where it is exposed, this is seen to be the case. South of Lokurtullye in the Morun river, at Bagra, in the glen south of Futtipur, and lastly at Mopani in the Sitariva, the lower Damuda rocks are more or less clearly seen to be faulted against the older rocks.

The N. Boundary of these rocks is a fault.

Besides which it appears that the older (lower Damuda and Talcheer) and the newer (Mahadeva) boundaries are generally, though not exactly, parallel. This is proved by the constant appearance of the former rocks, close on the south of the Mahadeva boundary, in most of the glens which have been hollowed out of the beds of the latter series. At Lokurtullye this is the case, again at Bagra, and in the little range which separates the Deinwa valley from that of the Nerbudda, the green mud and boulder beds often are found in the glens, close to the outer, or northern edge of the hills of this minor range. South of Futtipur, the same thing again occurs; and it is evident that these conditions could not obtain unless, as

Parallel Boundaries.

we have stated, the older and newer boundaries had been approximately parallel. That they are not absolutely so is proved by the Sitariva section (above quoted) where, instead of keeping south of the Mahadeva boundary line, the older sandstones &c. are found north of it.

We thus have, for this part of our area, two distinct fault boundaries, namely, that of the lower Damuda or Talcheer, and that of the Mahadeva, nearly coincident at many points, and approximately, though not quite, parallel. And there is abundant proof that the fault producing the older boundary existed; and that the rocks had been denuded before the deposition of the newer rocks. As for instance, in Futtipur glen, where the Talcheer conglomerate is faulted against the crystalline rocks, and their faulted junction overlaid by the continuous and nearly horizontal Mahadeva conglomerate beds.

Mahadevas unconformable to the older boundary.

Passing now to the south side of the Gondwarra hills, (see map) we have the boundary, in this direction, between the crystalline and the Talcheer rocks stretching east and west, and maintaining the strongly rectilinear direction so characteristic of the boundaries already described.

South boundary of the Talcheer.

This boundary runs from a little west of the meridian of Bétúl, to a little east of that of Chindwarra, and is in both directions hidden by the overlying Trap. It may be traced along the base of a well marked range of hills of the crystalline rocks, which run nearly east and west, and some of whose peaks rise to a considerable height above the valleys below. Two of the most remarkable of these are Persakote, and Muttardeo, each of which is formed of, and its prominence due to, a very hard bed of quartzite, part of the schist series here. This rock is mostly gneissose, and in places hornblendic, and its intense hardness has resisted the denuding forces which have removed from either side of it the softer layers of micaceous and friable schists. The strike of the rocks is, as nearly as can be estimated, east and west; and to any one

looking from the east or from the west, at Muttardeo, or Persakote hills, they appear to be very steep cones, or in some points of view almost vertical pillars of rock; looked at however from the north, or south, the profile is very different. They then appear as flat topped hills, with sloping sides, and the whole range to which they belong is much less picturesque in outline when seen from this, than from the former direction.*

At the base of both these hills and close under the foot of Muttardeo, the soft green muds of the Talcheer group are found.

Physical character of the boundary.

The observer will on the ground be struck by the fact that the contour of the Muttardeo range is the result of the relative hardness of different members of the schist series, and he will probably be at first led to the conclusion that this part of the Talcheer basin, was, when those beds were originally being deposited, very nearly identical in outline with the existing valleys along the south side of the area now occupied by the rocks of the group. He will perceive that the lowest of the Talcheer beds are often here exposed as in the Rawundeo section, (see *Fig.* 5, p. 152,) and he will see that the direction of the strike of the crystalline rocks closely coincides with that of their boundary, even where this boundary is most clearly rectilinear; and however remarkable this straight line direction may be, it thus seems accounted for satisfactorily by referring it to the original form of the basin of deposit, a form impressed on that basin by the structure of the

Fig. 18. Section seen in a branch of the Tawa river, near Muttardeo.

crystalline rocks. Still much, perhaps most, of this boundary is certainly faulted, as is seen to be the case in many places along its line. *Fig.* 18, shows a case of this, many instances similar to which might be adduced.

* Report on Coal Field of Talcheer, Cuttack. Memoirs of Geol. Survey of India, Vol. I, p. 34.

Remarks on this section.

A little to the east of Muttardeo the Tawa river runs close under the base of a spur of the range, of which a section is given in the diagram, *Fig.* 18. This section is exposed in a little ravine draining into the Tawa at the place. The cliff over the Tawa is composed of the green mud, and earthy sandstone of the Talcheer group, (*b*) here considerably indurated; and the induration is visibly due to an infiltration of quartz. It increases in intensity towards the south, until at the fault line the rock has become a very hard brecciated mass, retaining little of the original aspect. In the ravine, this is well seen, and the vertical beds of the schist series (*a*) (here hornblendic gneiss) may be observed in close contact with the breccia, as shewn in diagram. Many parallel ravines shew equally well all the same features repeated, and it is certain that the boundary, considered as a whole, is a fault, at all events east from Muttardeo. To the west of that hill, it appears to be of a mixed character, sometimes faulted, sometimes not. Probably the north face of Bowerghur is also a fault (see *Fig.* 4, p. 151). The hill is formed of granite, and granitic gneiss, and has a sheer precipice of 800 feet on the north, at the base of which the Talcheer beds occupy the flat.

Another case.

This south boundary of the Talcheer rocks, taken as a whole, is, as may be seen from the map, parallel to the boundary fault which forms the south side of the Nerbudda valley, and which is (speaking generally) the north boundary of these same rocks, as well as of the Mahadeva beds, as before described.

It is, of course, not intended to assert that this parallelism is exact, but it is nevertheless a very striking geological feature in the district. No one of these boundaries of the rocks, more recent than the Vindhyans, is exclusively a faulted boundary, the newer are on the contrary not unfrequently seen resting on the schists, as for instance near Salibanta in the Salya section and elsewhere: but it is certain that the general direction of each of them was defined by a fault along the greater

part of them. These lines may all be distinctly seen to be faulted, and in every case where the newer beds are seen to rest on the old crystalline rocks, we find that the junction is always *within*, and never *outside* the general line of the fault.

The Vindhyan Fault Boundary.—In the first pages of this report the general aspect of the Vindhyan boundary has been described. This scarp forms certainly the most striking feature in the scenery of this part of Central India, and is most important considered as a geological phenomenon.

General aspect rectilinear.

The first thing to strike the observer, and which may be noticed even by inspecting the accompanying maps, is the well preserved rectilinear direction of the boundary line. The great escarpment is, as has been stated, varied along this line, by many projecting promontories, and receding bays; and the boundaries of the alluvium, traced on our maps, somewhat disguise the true boundary of the Vindhyan sandstones. If this were shewn, it would appear that, though the escarpment has been often cut back into bays, yet that the true boundary of the rocks beneath would much more nearly coincide with the line joining the opposite bluffs of such bays, than with the alluvium boundary which follows the contours of the present surface. Moreover the deviations from the rectilinear direction are often seen to be curiously rectilinear in detail; that is, the approximately straight line of the general boundary is made up of shorter straight lines, and not, as might be conceived from an inspection of the map, of the curved outlines of the boundary of the rocks as determined relatively to the alluvium.

No Vindhyans on the south of the valley.

Little less striking than this rectilinear feature, it will be noticed that the boundary is, as far as our area is concerned absolute and complete, that is, no vestige of the Vindhyan rocks is known to occur south of it. All those rocks from the Talcheer up, which are so frequently seen, on the south of the

Nerbudda valley, have nowhere been found resting on Vindhyan beds, even where, as is sometime the case, these come within 12 or 15 miles of the boundary we are now describing. If the Vindhyan rocks ever stretched thus far to the south of their present boundary, they were all removed prior to the deposition of any of these lower formations. It certainly seems extremely improbable that such a formation had an original coast line so straight as its present boundary, and it is difficult to escape the conviction that the beds of this series must once have stretched farther to the south than 12 or 15 miles from their actual limit in that direction: this conviction, moreover, is strengthened by the absence all along the Vindhyan boundary of any thing like shore deposits.

Original extension of the Vindhyan rocks.

It has been shown that in the cases of the Mahadeva group, ample indications of the old coast line exist, where the faulted boundary coincided or nearly coincided with it. No such indications have ever been detected along the Vindhyan boundary line, every thing, on the contrary, suggests that the very homogeneous rocks found along that line, were formed under the same conditions with the vast spread of similar deposits extending over Bundelkund and Rewah.

From these two considerations, namely the rectilinear direction of the boundary, and the fact of its certainly not being the original limit of the basin of deposit of the formation, we come to the conclusion that it has been determined by a great line of fault. But the observer in the field will have this conviction forced on him by evidence of the fact that the line we are describing is itself, at many points along its course, a fault with a down-throw to the north. We shall now instance some cases where this is well seen. Near the junction of the Hiran River with the Nerbudda, both eastwards along the right bank of the former, and westward along the right bank of the latter, many fine and instructive

Conclusion suggested by these considerations.

Confirmation of this conclusion.

Examples.

sections are exposed, as near Putria village, near Kotri, north of Hirapur, north of Kerapassi (see Section No. IV on map and which may serve as an example typical of these cases).

The general character is as follows:

Description.

The nearly horizontal beds of the Vindhyan series are cut off in a vertical scarp, and at a short distance south of this, a mass of sandstone is found often rising in a conical hill, or a saddle-backed east and west ridge, to nearly the height of the top of the escarpment, as represented in the diagram referred to. This hill or ridge is formed of vertically, or nearly vertically-bedded rock, often very similar to that of the neighbouring escarpment, but more frequently showing traces of a lithological alteration. It is, when this is the case, traversed by numerous quartz veins, and looks as if the rock itself had been impregnated with infiltered silica. Often this *altered* character is very greatly developed, and the rock then becomes a breccia, formed apparently of fragments of shattered sandstones re-cemented by infiltered quartz. Immediately behind, (that is south of) this breccia, we generally find the schists (see diagram Section IV) of the Nerbudda valley. Here there is an evident case of a fault with a down-throw towards the north, whose course is marked by the upturned bed of sandstone, and by the breccia.

Less well marked case.

In the localities above named these features can, as stated, be clearly seen; elsewhere we only find traces of the breccia, and not a prominent hill formed of it, to the south of which traces of the schists appear, indications which are, however, sufficiently explained by the better seen sections such as those above described.

Pulassi Section.

But the nature of this fault is perhaps still better seen near a little village called Pullassi, which is shewn at the western extremity of our smaller map. Here the Nerbudda River runs between the Vindhyan scarp and the breccia line,

and exposes a series of beds whose position throws considerable light on the question.

Fig. 19. Sketch section of the rocks as seen near Pullassi.

It is here evident that the vertical bed, *(c)* seen forming an island in the Nerbudda, is the upturned prolongation of one which underlies those seen in the escarpment on the right bank, (*a*) and that its position is probably the result of the disturbances which produced the breccia (*b*) exposed just behind (south of) it on the left bank. Elsewhere the trap, the alluvium, or some of the formations more recent than this fault, conceal or obscure the features here so well exposed, but no case is known where any of these features is out of place; the breccia line, for instance, is never seen north of the vertical bed of sandstone; nor are the schists ever found between the latter and the Vindhyan escarpment.

Some minor indications of disturbances, unconnected with boundary lines.—Among the many rocks already described or occurring within the area included in our map, few appear more frequently in the valley of the Nerbudda, or attract the attention of the geologist more, than one which we still have to notice. It generally is found in amorphous masses of a reddish color, sometimes with a honey-combed surface as if from the weathering of a porous or vesicular rock, sometimes presenting smooth rounded outlines with the polished metallic look so well known as characteristic of *laterite*. It is extremely tough, has a conchoidal fracture, and the freshly broken surface often presents a horny flint-like appearance. On such a surface there may generally be traced the outlines of angular fragments enclosed

Description of the Breccia.

in the rock; commonly however the material of which the enclosed fragments are composed is so similar to the matrix in which they are embedded, that it is often difficult to detect their presence. Sometimes a slight difference in color, or texture, between the two, suggests the true state of the case. Just below Bhera ghat on the Nerbudda, a good example of this occurs; and the rock here presents a somewhat striking aspect. The matrix is brick red, and the enclosed pebbles and fragments are white vein-quartz; the mass weathers with a brown red color all over, but on a fresh fracture the colored and uncolored portions contrast strongly. And there can be no doubt that a rock of white quartz was crushed to pieces and had its fragments re-cemented by a substance very similar to the original rock, but colored by some ferruginous impurity. Pages might be filled with descriptions of the many lithological peculiarities of this breccia but although this is of course unnecessary there is one so generally characteristic of the rock, in almost every place where it appears, as to require special mention. I allude to the occurrence of pseudomorphous cavities in the flinty matrix. They are the hollows left by irregular nests of flat tabular crystals, but are never sufficiently well defined to shew certainly to what individual mineral they are due.*

The extreme hardness and toughness of the breccia have protected it from the effects of denudation, and it forms almost always, the summit of all the minor hills which rise from the flat ground of the Nerbudda valley, and may in many places be traced at the surface protruding through the black soil. Although the above description will be found of pretty general application, yet the rock we are considering is by no means constant to the characters indicated; on the contrary its varieties are very numerous. Sometimes indeed the enclosed fragments are not only distinct from the matrix, but differ among themselves and may be

* A similar rock is widely spread in different parts of India. See Talcheer Report Mem. Geol. Surv. of India, Vol. I, page 72. &c.

identified with the different beds of the schist series, and the true breccia character of the rock is then well seen.

Mode of occurrence.

Examined on the large scale, this breccia is found always to occur in lines, like the outcrop of a bed. But in places where the schists and gneiss of the metamorphic series are well exposed, and where at the same time the breccia lines can be clearly traced, the latter are found not to coincide with, or to lie parallel to the strike of the former. Both have (roughly) an east and west direction, but the line of breccia is sometimes seen to cut obliquely across the outcrop of several varieties of the schists successively.

Conclusion suggested.

Thus it would appear that these lines of breccia mark the direction in which some disturbing force has crushed and fractured the rocks, so as to form the mass of fragments, which recemented together by a quartz matrix, go to form the breccia.

Agrees with lithological character.

It has been already noticed, that generally, the enclosed fragments of the breccia are siliceous, and very often quartz, and the preponderance of this ingredient may be accounted for (on the above hypothesis of the breccia being a fault-rock) by the fact that the fragments are principally derived from the hardest bands of the schists, and are those which would naturally resist best the effects of such mechanical violence, as we suppose to have been the cause of the breccia.

It has also been stated that fragments of other members of the schist group often occur. These are, it is true, not often capable of being identified with the different varieties of the schists, and referred to this, or to that bed, but as far as such identification is possible, they are always referrible to those beds in the immediate neighbourhood: and no case has been known of a recognizable fragment which belonged to a rock not seen close by. In one case the breccia, both matrix and fragments,

became calcareous, when passing across the outcrop of the crystalline limestone; fragments of this rock were here enclosed in a matrix of the usual flinty aspect, but which was found to be strongly impregnated with carbonate of lime.

Examples of this Breccia.

Passing from Dilheri village (see map) to Hinhotia, and eastwards from thence to Gungye, the observer will not fail to be struck with the aspect of many small hills which rise from the plain.

They will be seen to affect a general east and west direction, and sometimes to form pretty continuous ridges, parallel to the general line of the bounding range of the valley. The beds of the schists along here are nearly vertical, and these hills at first seem to be formed of some of these vertical beds, harder than those around, and which from this cause have resisted denudation, and remained as a hill while the softer beds around were removed. It is soon found, however, that the direction of the hill ridges is not that of the strike of the schist beds, all the varieties of which may in turn be found at their base, but that these ridges owe their existence to the breccia. This rock is always found on the summit, it may almost always be traced up the east and west sides of these hills, and sometimes across the flat ground from the east of one to the west of another of them, while on the north and south the schist beds only are seen, except that in most cases fallen masses of the breccia greatly obscure the real structure of the ground, and in some these are so numerous on the north and south slopes of the hills that it is impossible to discover where the breccia is in place, and where only accidentally present, as fallen from the higher part of the hill.

Many other cases might be pointed out where lines of this breccia mark the direction of disturbances which have affected the area occupied by the metamorphic rocks of our district, and these are shown on the map by white lines. But the evidence of faulting derivable from such cases is not confined to these older formations.

Breccia lines among some of the newer formations.

In a section exposed by the Kanhan River a couple of miles north of the village and old fort of Hurriaghur, a line of fault rock is crossed, which traverses the Damuda sandstones. The beds normally soft, friable felspathic sandstone have become glassy quartzite, as if hardened by heat, numerous veins of quartz and nests of vein-quartz are seen to permeate the mass, which weathers with a honey-combed surface from the unequal hardness of its component parts, and it becomes apparent that the original rock has been crushed and shattered by mechanical violence, and recemented by infiltered silica into the hard flinty mass we now find it. The continuation of this line may be traced across the flat country by the numerous blocks of white vein-quartz which mark its course, and which seem to have been derived from a great quartz vein or dyke. When more closely examined, however, the true breccia was always found to be the source from which the fragments came, and its out-crop is, as stated, marked by their presence. Many of the minor hills which rise parallel and near to the south boundary of the lower Damuda and Talcheer rocks of our map, are due to the great hardness of this breccia. The Muchna River flows close under one of these a mile north east of Shapur; the range which separates the valley of the Sooki Nulla from that of the Bhora is another case of the same phenomenon. Another well marked ridge of breccia runs across the flat ground farther to the east, or south east, and near it the villages of Moka and Banspura may be seen on our map: again Rawundeo hill is formed of the same rock, and its nature and habits may be well studied there.

Examples of this.

Effect of these on the sandstone.

Where these lines of breccia traverse the sandstone beds, that rock is, as has been stated, much cut up by little veins of white quartz, and the mass seems permeated, saturated as it were, with infiltered silica, the traces of original structure and bedding are obliterated, and a vertical jointing generally obtains

which itself closely resembles bedding, and has been taken for it.

Amount of vertical displacement.

In no case has it been found possible to estimate the amount of vertical displacement of the fault marked by the breccia, nor even to ascertain on which side of it the down-throw has taken place. Not so however with the direction of the line of fracture.

Direction of the lines horizontally.

This is rendered the more visible by those very causes which obscure all evidence bearing on the former questions, and it can generally be traced with great exactness over considerable distances. This direction is always nearly from east to west, and as far as our imperfect maps permit of such an assertion, parallel to the south boundary of the lower Damuda and Talcheer rocks. The same direction holds with regard to the breccia lines first spoken of within the Nerbudda valley itself. These are parallel to the great Mahadeva fault near which most of them can be traced.

Fig. 22. Range of the Puchmurri or Mahadeva Hills, seen from the South, shewing the great escarpment.

Farther considerations connected with disturbance.

But there is still another fact to be noticed which bears on the question of the disturbances of which our district has been the theatre.

It has been stated that the general direction of the southern boundary of the lower Damuda and Talcheer rocks is parallel to that of the northern boundary of the same rocks, and of the Mahadevas, but it may further be seen from the map, and is very strikingly apparent on the ground, that all the valleys of the area inclosed between these limits, are also parallel to these boundary lines. Ranges of hills run east and west whose steeper face is generally towards the south, and the more gentle slope northwards. Chatur Doria, and the outer range thence to Bogra and the Tawa, is succeeded on the south by the great physical feature of the district, that range of which the lofty mass of the Puchmurri is the culminating point. This ridge presents a nearly continuous vertical cliff facing south, (*Fig.* 22, p. 249,) throughout the whole of its length, which stretches many miles to the west from Puchmurri. Parallel to and south of this again, and imitating on a smaller scale all its principal features, we find another east and west ridge, with a precipitous face towards the south, in which Gidundeo and Mandeo Peaks rise to a considerable height. Asseerghur fort stands on a ridge still further to the south, which keeps a similarly parallel direction; and finally, between this range and the southern boundary of the Talcheer beds, (itself marked by the lofty east and west range of Persakote and Muttardeo) we find another great ridge, both the north and south face of which present sheer escarpments and steep slopes. All these are, as has been stated, indicated on our map, but they form on the ground very remarkable and striking features in the physical aspect of the district, and impress the observer strongly with the conviction that the parallelism which has been stamped in such characters on the structure of the whole country, must be due to some uniform and widely acting causes.

Parallel valleys.

It may be well to remark here, that the great majority of the trap

dykes found within this area take the same course, and run more or less exactly east and west. This fact may also be noticed on the map. Many exceptions to the rule occur, as may also be seen, but the general tendency is not the less remarkable.

Trap dykes.

Of the age of the Faults.

When describing the faults, I reserved the question of their relative ages for separate discussion, principally because it involves considerations more hypothetical than any thing hitherto advanced, and which, for this reason, it seemed advisable to keep distinct from the simple description of phenomena.

Hypothetical nature of the enquiry.

In the foregoing pages the fault systems traceable throughout our district have been described separately, under the following heads.—

1st. The Mahadeva fault, that which forms the north boundary of the Mahadeva, and Lamèta groups, and, towards the north east, of the upper Damuda rocks.

2nd. The faults which form the boundaries of the lower Damuda and Talcheer group, one on the north, and one on the south.

3rd. The Vindhyan fault, forming the boundary on the south of that great series.

4th. The great number of smaller disturbances, whose existence and direction are marked by the lines of breccia: these are grouped together for convenience sake alone, as there is no evidence that all these faults have been produced at the same time or even within the same geological *period*.

Considering these systems of faults, as thus classified, the question of their relative age is beset by many difficulties. All those movements of which we can trace the results among the more recent deposits, must of course have affected the underlying and more ancient formations as well, and must therefore have often obscured, or altogether effaced, the traces

Newer disturbances effacing the traces of older.

of prior disturbances among these, which prior disturbances may, nevertheless, have been originally of far greater magnitude than those newer in date, and whose results are now more prominent.

Instances of this.

A remarkable case of this occurs in connection with the Mahadeva fault, which, as has already been pointed out, runs nearly parallel to, and hides, except in a very few localities, the older fault line which had formed the north boundary of the Talcheer and lower Damuda rocks, prior to the deposition of the Mahadeva beds. Of the relative ages however of these two faults there can be no doubt, and we know, that the fault, which bounds the Talcheer and lower Damuda group on the south side, existed prior to the deposition of even the upper Damudas; for in the Mahanuddi and Johilla valleys we find the beds of that latter series horizontally overlying the faulted junction between the older sandstone and the crystalline rocks. With regard then to the relative ages of No. 1 and No. 2 the evidence may be considered satisfactory.

No. 1 and No. 2, can be clearly fixed.

With regard to No. 4, nothing, as has been stated, can be positively asserted; and these minor faults may, without violating any probabilities, be referred to the most recent epoch of disturbance.

No. 4, both questionable and unimportant.

It remains to deal with No. 3, which presents by far the most interesting and at the same time most difficult problem of all; namely to determine what, relatively to fault No. 1 and fault No. 2, is the age of the great Vindhyan fault.

No. 3.

If we consider the general character of the rocks of the Vindhyan formation throughout the immense area occupied by them, it is difficult to believe that they were originally bounded on the south by a line either coincident with, or nearly approaching to that of their existing fault boundary; or to escape the conviction that they once stretched far to the south of their present limits in this direction.

In other words, we must conclude, that no part of the present faulted

south boundary now lies very near to what was the southern shore of the original basin of deposit of the rocks. The study of the phenomena developed along the Mahadeva fault, will render the observer familiar with the readily recognized indications of the proximity of the shore presented by rocks which have been formed under such conditions. But no where does the Vindhyan scarp expose any thing like a littoral bed. On the contrary, the homogeneous character is as well preserved here as elsewhere throughout the rocks, and the beds at the scarp seem perfectly identical with those found in the most typical sections of the formation away from it. There is then every reason to suppose that the Vindhyan sandstone beds did once stretch far to the south of their present actual boundary. No where, however, have they ever been found to underlie any of the sandstones, from the Talcheer beds up to the Lamèta group inclusive. If they had any where done so the fact could scarcely have escaped observation, but all the rocks of the great sandstone series on the south side of the Nerbudda are invariably found resting on or faulted against the old crystalline rocks, when their boundary is reached.

Present S. boundary of Vindhyan not near ancient limits of basin of the deposit.

Vindhyan once stretched far to the south.

Now, if the Vindhyan fault be supposed to have existed prior to the deposition of the lowest Talcheer beds, then, as that fault was (see above) a downthrow on the north, and would naturally have facilitated the complete removal by denudation, of all the Vindhyan beds on the south side of it, we have a ready explanation of the absence of those rocks under all the newer sandstones &c., in this direction.

No. 3 older than the Talcheers.

If, on the other hand, we suppose that the Talcheer beds were deposited before the fault shifted the Vindhyan rocks, we are met by the difficulty of accounting for the complete removal of the Vindhyan beds up to a nearly straight line several hundred miles long, and in such a manner that a vast thickness

Difficulty of contrary supposition.

of them remained along where their present boundary line runs, while from 10 to 15 miles south of that line no trace of them was left. The fault, as has been stated, fully accounts for all this; but it is difficult to realize in imagination any condition under which such could, prior to the fault, have been effected. From these considerations we are led to the conclusion that the Vindhyan fault is almost certainly older than the lowest Talcheer beds, and therefore of course than faults No. 1 and No. 2. It would then be the most ancient of which we have any evidence in the district. The Vindhyan beds which had been elevated on the south side of it were removed by denudation before the deposition of the lowest Talcheer beds. Many of the beds of that, and of the lower Damuda groups being possibly formed of the materials, furnished by that denudation.

Conclusion.

Supposed state of the case.

Subsequently to the accumulation and consolidation of a great thickness of these Talcheer and lower Damuda groups, the faults No. 2, now marking the north and south boundaries of the formation, cut off its beds; the fault on the south side of the field being a down-throw to the north, and that on the north side of it being a down-throw to the south.

The upper Damuda and Mahadeva rocks were then deposited, overlapping frequently the limits of the older sandstones, and their limits of extension to the north were subsequently fixed by the last disturbance to which we are able to assign a date, *viz.*, the Mahadeva fault.

A very interesting question arises in connection with the parallelism which exists between these different systems of faults. This phenomenon has been pointed out when the direction of the several faults was under discussion. With reference to the Mahadeva and the Vindhyan faults (No. 1 and No. 3 of our list) a glance at the map will show how very

Further considerations suggested by the parallelism above described.

striking a feature this parallelism forms in the geological structure of the country, and if the Vindhyan fault be considered through its course from Mundlaisir to Rotasgur (see smaller map), the extent of length along which this parallelism, or approximate parallelism, exists is very considerable. The continuity in rectilinear direction of the faults No. 2 (the boundary faults of the lower Damuda and Talcheer rocks) has not been followed out to any thing like the same extent, but enough is known to show that they too are approximately parallel to the others. The direction of all these fault lines is capable of being determined with an exactness seldom attainable in measuring that of hill ranges, while at the same time the great length to which they are known to extend, and the very important part they play in the physical geography of the country, certainly entitle them to be ranked with the results of those great movements in the earth's crust to which the elevation of mountain chains has been attributed.

Considered from this point of view, the results at which we have arrived, go to show that in our district important displacements of the rocks of several distinct formations, along lines rectilinear in directions for great distances, and remarkably parallel to each other, are due to movements which were not synchronous, but on the contrary occurred at intervals separated by the lapse of whole geological epochs.

Referring to the list of faults given above (page 250,) we have in the first place faults No. 1 and No. 2 demonstrably of distinct age; the older can be proved anterior to the deposition of the upper Damudas, and the more recent subsequent to the consolidation of the Lamèta beds.

I have endeavoured to show that the Vindhyan fault is older than the oldest Talcheer beds. If the evidence adduced in support of this view be considered sufficient to establish it as a fact, we then have another great fault line parallel to each of the former fault systems, and separated in age from the more ancient of those by the whole period during

which the Talcheer and lower Damuda formations were being deposited. If, however, the distinctness in age of the Vindhyan fault be considered as unproven, (although probable,) it may be assumed to be synchronous with fault No. 2, in which case we shall have those supposed synchronous faults, No. 3 and No. 2, parallel to the fault line No. 1, proved to be of a different geological date.

Or, the Vindhyan fault may be assumed to have been synchronous with No. 1, in which case we still have the supposed synchronous faults No. 1 and No. 3, parallel to the fault No. 2, proved to be of a different geological date. We believe, however, that the evidence brought forward is sufficient to establish the stronger case, namely the distinctness in age of the three great fault lines described, and that we have in the lines of breccia, and again in the constant direction of the valleys and escarpments of the interior of the Mahadeva range, evidence which proves that a tendency to yield in general east and west or more nearly north-east and south-west lines has existed in this great area from the remote period of the Vindhyan fault, up to that of the most recent movements which have left any traces in the rocks of the country.

There is another point of view from which the subject of the faults and disturbances of this district may be considered. It is evident that the following conclusions may readily be deduced from the contents of the preceding pages.

1st. We have in this district a rectilinear range of hills of great length.

2nd. A second range also exists, strikingly rectilinear, and parallel to the former, although not quite so perfect, or continuous as a range, nor so accurately rectilinear as the former.

3rd. The line of each of these ranges is coincident with a geological boundary.

4th. Each of these geological boundaries is a fault.

5th. The interval of a geological period elapsed between the production of these faults.

With reference to this last question, namely the age of the faults, it must of course be remembered that relative age only is considered: and that when we speak of one fault as of a different age from another, we only mean that after the former, and before the latter, a cycle of geological events ran its course; some area had, from one of denudation, become one of deposition, beds had been formed, consolidated, disturbed &c. Whenever there is evidence, as in the examples adduced, to show that this was the case, we speak of the faults as of different geological ages, irrespective of the absolute ages, or position in the geological scale, of the two formations, from the examination of which we derive the proof.

Those who may remember the theory of the synchronism of parallel mountain chains, proposed by M. E. de Beaumont, cannot fail, while perusing the foregoing pages, to have remarked, that many of the conditions necessary for the investigation and application of that theory are here exceptionally well developed. The theory asserts that those vast movements which caused fissures in the earth's crust, the direction of which fissures is now marked by mountain chains, acted, wherever produced at the same time, in lines parallel in direction, even when they took effect on portions of the surface far apart from each other. And that, therefore, mountain chains, and great lines of dislocation, whether close to each other, or in the most distant parts of the earth, where parallel in direction, may be referred to the same, or synchronous, internal movements as their cause.

It is needless to point out how important a step towards establishing European equivalents for our Indian rock systems we should have made, could we fix the age of such movements as that which produced the Vindhyan range, relatively to that of some of the twenty geological dates assigned by M. de Beaumont to the principal systems of mountains and great fault lines of Europe.

M. de Beaumont has already himself offered some suggestions on this

subject (*a*), and holds out the hope that when our Asiatic hill ranges shall have been more thoroughly explored, the date of the movements to which their elevations are, in his opinion, due, will, even in detail, be fixed relatively to his European systems of mountains. He has spoken of this very Vindhyan range, and quotes a classification, proposed by Captain Newbold, in which the Vindhyan forms one of five great systems under which that geologist groups the Mountain systems of India. Our own observations have led to a result different from Captain Newbold's as to the true direction to be assigned to the Vindhyan range, and consequently of course to a different estimate of its probable geological age according to the theory. It is possible that his estimate may have been derived from observations made in the Sautpoora range to the south, and not in the so called Vindhyan range itself; and at any rate our estimate must of course rest on what we believe to be more extended and careful observations.

Before proceeding to discuss that estimate, we may remark that in applying a portion of M. de Beaumont's theory, we keep quite clear of other parts of it; that in seeking to determine the relative ages of disturbances which have affected parts of the earth's crust widely separated from each other, we leave untouched the question of the *manner* in which such movements took place. They may, as M. de Beaumont supposes, have been the result of great shocks, cataclysms which suddenly changed the whole character of the surface over vast areas, or they may mark the final result of an uplifting, or a depressing agent, which for any conceivable length of time, so slowly shifted the rock masses, as to have been inappreciable at any one moment. The only limit necessary for us is, that, if gradual, the movement commenced after the consolidation of one set of beds, and had ceased before the deposition of another set.

We have shown above that several lines marked by hill ranges and dislocations of the rocks may be traced in this district, all more or less

(*a*) Elie de Beaumont. Systèmes des Montagnes, Vol. II, p. 646, Paris 1852.

accurately parallel to each other. We shall here, however, confine our attention to two only of these, namely, to that lying immediately to the north, and to that immediately to the south of the Nerbudda Valley; the ranges of the Vindhyan, and of the Mahadeva faults, respectively. Sacrificing much of the cumulative force derivable from the mass of facts connected with all these range lines, we shall gain something in thus simplifying our case.

Taking first the Vindhyan range, with the intention of applying to it M. de Beaumont's theory, in order to establish a synchronism between it and some one of those European ranges whose geological date has been fixed by his theory, the first difficulty we encounter is inherent in the very initial step of the investigation: it is that of fixing the direction of any given mountain range.

The theory proceeds on the assumption that the elevation of a range of hills is the result of a rectilinear fissure in the earth's crust; and our problem is to trace on a map the exact position of that fissure. Causes, subsequent to this first origin of the range, must have changed the aspect of the surface; the accidents of denudation, and the resistance to its forces, offered by unequal hardness in different parts of the rock masses, must have indefinitely obscured the results of the original movements. We have, however, to estimate, from the modified contours of the surface, the exact position of this fissure line, which at best was one only of many causes that contributed to fix the form of the hills and valleys of which the range is made up. Captain Newbold was an observer whose accuracy and great zeal no Indian geologist will doubt. He assigned to the Vindhyan range a direction of W. 5° S. But whether we take up our best geographical maps, or refer to detailed observations on the ground; whether we take the range within its narrower limits, say from Hindia to Jubbulpur, or trace it to its extreme (*a*) length from the sea

(*a*) We exclude the hypothetical prolongations of the line east of the Ganges, nor does Captain Newbold, as far as we know, take such into his estimate.

on the west to the Ganges alluvium on the east, we will find equal difficulty in reconciling this estimate with facts. The explanation suggested above is very unsatisfactory, namely, that this direction was taken from the range between the Nerbudda and the Taptee, and the prolongation of that line south of the Sone. If however, as we have above shown, the movement to which the ranges north of the Nerbudda and the Sone owe their elevation, was certainly separated in geological chronology from that movement which traced the great fault lines along the south of those rivers, by a geological era, by the period of a cycle of geological changes as above defined, then it is simply an abuse of language to talk of the ranges as due to one movement as their cause, and a false generalization to group together the nearly parallel ranges, and taking an average from the whole, to speak of that as the direction of *a range*, and the result of a single effort of some internal force.

Such considerations may remind the geological reader of some of the difficulties of arriving at a satisfactory estimate of the simple direction of any hill range, when looked at in the light required by the theory under discussion.

After having overcome this difficulty, which is in our case reduced to a minimum by the exceptionally sharply defined line of the Vindhyan scarp, (and indeed also of the Mahadeva fault) and having so satisfactorily determined the direction of *two such ranges* as to feel safe in applying mathematical calculation to the result, we proceed to compare these directions. In our case the *two such ranges* just mentioned, are unnecessary; for we use M. de Beaumont's 20 European systems as standards of reference, and have to determine which (if any) among them was synchronous in origin with the Indian range whose direction we have fixed.

In attempting to investigate the parallelism of two lines so far apart on the sphere as those with which we have thus to do, it is evident that the question is not one of ordinary plane-surface parallelism. The

relative directions of these lines on the sphere must be estimated with reference to great circles of the sphere. The difficulty here consists in not over-stretching the limits of probability in the estimation of the modifying causes inseparable from such calculations, for the sake of a symmetrical result; a difficulty which cannot fail to strike any one who has carefully studied M. de Beaumont's great work.

But after making an estimate, or obtaining from a general estimation of the facts, a knowledge of the direction of our range-lines sufficiently exact to warrant the application of those mathematical calculations, to which we must have recourse in investigating the parallelism of lines far apart on the sphere; and after having found a parallel for our Asiatic range-lines among the European systems adopted as our standard, the next difficulty is found in the rarity of examples in which the lines thus fixed for the directions of ranges, so definitely coincide with geological boundaries, or are in other ways so clearly connected with geological facts as to furnish us with data for arriving at a really satisfactory determination of these geological ages. It is self-evident that however clearly determinable the direction of the ranges, or however certainly attributable to great fissure or fault lines they may be, still if they be not very definitely connected with the boundaries between other disturbances of rocks, demonstrably distinct in age, little or nothing can safely be concluded as to their own relative position in geological chronology (*a*).

Difficulties such as these, in the application of this theory, have been strongly insisted upon, and been by some considered, we believe, as sufficient ground, for its rejection; but, as before stated, the district with which we have to do furnishes us with conditions very favorable for its application here. The line of the range (a matter often so difficult to determine) is here traced unmistakeably and definitely.

(*a*) As a case in point we may refer to Sir C. Lyell's Analysis of M. de Beaumont's views concerning the age of the elevation of the main chain of the Pyrenees. Principles of Geology, IXth. Edition, 1853, p. 163.

It is a straight line; it is of sufficient length; it is unequivocally the line of a fault or fissure; and it is a geological boundary, absolute and definite throughout its course.

We may then take the line of the Vindhyan escarpment with great confidence for comparison with the 20 European systems of De Beaumont. We fix a great circle of reference, transfer its direction to a European equivalent, and attain an approximation to one of the European range systems, sufficiently close to suggest an age, according to the theory, for the great Vindhyan fault. The approximation is, at all events, as close as many included in the calculations on which these 20 Eurôpean systems are themselves based.

But we have now to recall attention to our second great range line, that of the Mahadeva fault range. It also is sharply traced, is a straight line, is of considerable length, is certainly a fault line, and unmistakeably a geological boundary: besides, it lies so close to the line of the Vindhyan fault, that their relative directions may best be appreciated by considering them as lines on a plain surface.

We have been attempting to fix an age for the Vindhyan fault by referring it to the direction of some fault line in Europe, taken as a standard of reference, and whose parallelism is supposed to prove synchronous origin; while we have before us this line of the Mahadeva fault, parallel to it, close to it, and demonstrably separated from it by a geological era: it is palpable that our confidence in the result of the reference to M. de Beaumont's European range systems is destroyed by these considerations. Our attempt to arrive at the position in the geological scale of chronology of a fault line in Asia, by the processes above detailed, may be considered an illegitimate application of the theory: or our estimates of the true directions of the Vindhyan and Mahadeva fault lines, may not be sufficiently exact to warrant us in stating that their parallelism is as satisfactorily made out as is the relative directions of some of M. de Beaumont's European systems; moreover, that

savant himself furnishes us with examples among those systems of pairs of range lines, of different supposed age, which if produced into a juxtaposition such as we here have, would exhibit a parallelism perhaps even more complete than that which we attribute to the Vindhyan and the Mahadeva faults. Again, we may have neglected the modifying action of a more recent and nearly parallel movement on the physical features from which we have estimated the direction of the Vindhyan fault.

Aware of all these sources of error, and fully alive to the fact that neither the closeness of our acquaintance with the structure of the district, nor the exactness of our observations, even within that portion of it which we have more carefully examined, will warrant us in believing that the application of this theory can here be satisfactorily made, we still think that the objections we have felt justified in raising, and our reasons for such, may prove useful to the geologist who may at some future time more fully investigate this most important subject, as well as of some interest to the general reader.

CHAP. IV.—THE DENUDATION.

When discussing the question of the probable thickness of the schist series and of the metamorphic group generally (see ante p. 131.) some considerations were advanced which bear directly on the subject of the denudation of the district.

Curved beds.

We know that beds now seen to out-crop in parallel lines on the flat ground, and dipping in opposite directions, were once continuous, and that their curved prolongation upwards must have formed great masses of rock, long since cleared away. Evidence of this nature abounds; but besides this, many other considerations go still further to increase our estimate of the extent of denudation.

Denudation as suggested by the Vindhyan fault.

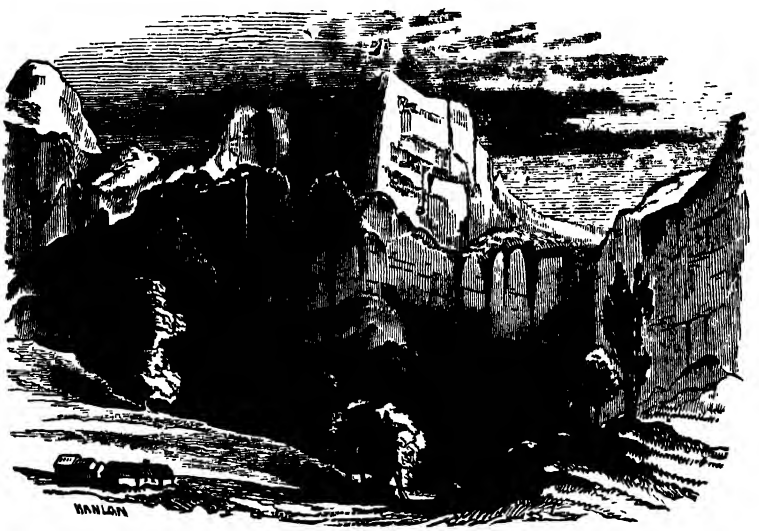
For instance, we know that the Vindhyan fault was a down-throw on the north, that is to say, the portion of the mass south of its line was raised above that north of it. Since then, however, this elevated portion has been removed, and the hill range now existing is that part of the mass which was at first depressed below its original (relative) level. What, in short, is now the Nerbudda valley must have been—just after the Vindhyan fault had shifted the position of the rocks—a range of hills or a line of escarpment looking down on a plain to the north. These facts show to what a vast denudation this part of the surface has been subjected. But this is not all; for we find on the south side of the valley evidence precisely analogous to what we have just described on the north of it.

Proved by the Mahadeva fault.

The Mahadeva fault was a down-throw to the south, so that here too the portion of the surface now lower in level was that relatively elevated by the fault. Subsequent then to the Mahadeva fault the denudation must have been enormous.

The sketch here given (*Fig.* 23) represents the aspect of the great Puchmurri escarpment as seen from a hill south of it. The observer

Fig. 23. View of the escarpment of the Puchmurri range, seen from the south.



stands on a bed of Mahadeva sandstone like that of the rocky precipice opposite to him, and probably a continuation of it; but on descending, he will find the flags and shales of the lower Damuda rocks, exposed in the deep gorge across which he is looking. This is a typical case; most of the glens of the upper Deinwa drainage afford similar examples, which also constantly recur in those of the Tawa tributaries (see map.) The tabular masses of the Mahadeva sandstone have been cut through, and in almost all these gorges, expose the older rock below. The valley of the Tawa itself affords an instance of the same thing on a larger scale. It can hardly be doubted that the tabular sandstone of Gidundeo, Asseer, and Jamghur (see map) was once all continuous, covering to a great thickness all the present Tawa valley, and forming part of the mass lying to the north in the prolongation of the

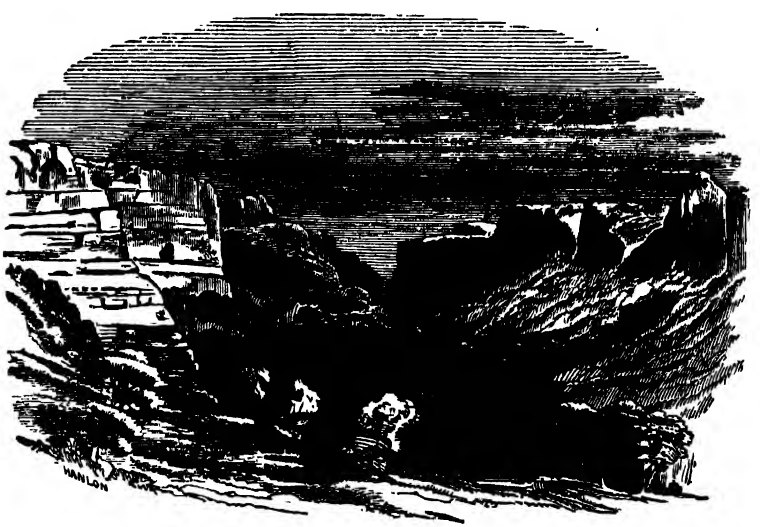
Proved by the valleys of the Gondwara range.

Puchmurri range westwards. These facts again prove the existence of a great denudation, where powerful agency must have been long at work to effect the results before us. But what may be called the minor features of the denudation of the great sandstone masses also present some striking peculiarities.

Farther evidence.

Fig. 24 represents one of the gorges of the Puchmurri Hills which will give a good idea of the characteristic outlines of the weathering of the sandstone masses. But the finest and most remarkable of these glens is that by which the Sahbudra river flows through the mass of the Puchmurri range to join the Deinwa on the north of it. The gorge is narrow, often not 300 feet across, and with almost vertical sides frequently 1,800 feet high.

Fig. 24. View of gorge in the Puchmurri Hills.



Having thus endeavoured to show the enormous extent of the denudation which has obtained by pointing out some of the more prominent evidences of the former existence of solid masses now removed, I shall

leave the question of the causes by which such effects have been brought about untouched.

The magnitude of the results prove that the forces at work must have been great; but little has been observed capable of suggesting any satisfactory explanation of their modes of operation.

THE writer of the preceding pages feels that they ought not to be published without a definite acknowledgment, on his part, of the aid he has received from the Superintendent of the Survey. Commencing with advice, suggestions, and encouragement in every difficulty which arose while the field work was in progress, Mr. Oldham's assistance has throughout ever been readily extended to him. He is more especially indebted to it for the correction of some of the more glaring defects in the form which he had given his paper; and he desires to record his sincere thanks for the many occasions on which he has profited by help so often, and so kindly, afforded.—(J. G. M.)

(APPENDIX. A.)

List of the principal out-crops of Coal within the area included in the accompanying Maps.

1. *Sitariva River*—near Mopani and Berar villages, (see detailed section ante page 169).—This place has been long known, it was reported on by Col. Ousley in 1835, mentioned in the Coal Committee's Reports, and by Messrs. Jacob and Blackwell since then. Four beds in all occur.

1	a	10 ft.	0	ins.	bed,	dip at about 25°.
2	„	2 „	6	„	do.	
3	„	5 „	0	„	do.	
4	„	4 „	0	„	do.	dips at 80°.

This locality is easily accessible and little above the general level of the Nerbudda valley.

2. *Rawundeo* : on the Tawa River near Salyia (see detailed description of this section ante page 154). 21 feet 2 inches of coal are seen in eight distinct outcrops, but in as much as some of these out-crops may be different parts of the same bed brought again to the surface by faults, it cannot be proved that the total aggregate thickness exceeds 10 feet 8 inches. This section has not been before described, it was first examined by the Survey in 1856, the coal is excellent in many of the beds, and the average thickness of three feet which is attained by the coal at four of its out-crops at least, together with the low dip which the beds have, will afford facilities for "*getting*" the coal cheaply, when it comes to be worked.

Shapur on the Betul and Hosungabad road is about 12 miles from the spot, and a branch road could easily be constructed. The place is however far from the Nerbudda valley.

3. *Machna*—near Kotri and Murdanpur villages. Seen in the bank of the Machna River, there are two seams, one six inches thick, shaly and impure ; the other three feet thick, dips at an angle of 30°, at the out-crop, and is of excellent quality. It comes to the surface about 3 miles from Shapur (on the Betul and Hosungabad road) and is thus more accessible than that at Rawundeo, to which, however, in all other respects it is inferior.

4. *Sonadi*—in the Bora Nuddi, two bands exist nineteen and ten inches thick respectively. This locality, mentioned by Col. Ousley, was successfully worked by Mr. Johnstone under the orders of Sir R. Hamilton of Indore. He sunk a shaft, besides cutting back on the out-crop, and found the coal of good quality. Some of it sent to Bombay for trial was found to be in many respects excellent though much injured by the mode of carriage. The Sonadi coal has since been examined by Mr. Jacob and others whose reports contain much information (*a*). The out-crop is not more than 6 to 8 miles from the Betul and Hosungabad road.

(*a*) Selection from Records of Bombay Government, No. XIV.

5. *Sooki Nulla.* Near the junction of this stream with the Tawa two thin seams of coal are seen, three inches, and two and a half inches thick respectively. They rapidly die out to mere threads, and patches, among the false bedding of the sandstone. A far too favorable view of this place has been taken by previous observers. Mr. Johnstone was of opinion that it might be worked profitably
6. *Morun River*—near Lokurtullye. A three feet seam of poor pyritous coal out-crops in the river bank with a very slight dip. First noticed by the Survey in 1856. Any importance attaching to this locality is derived from the fact of its being the most westerly of all the known out-crops. The Sonadi coal passed near this place on its way to Bombay, and before getting thus far, was carried on buffaloes, more than 30 miles over bad hill paths. The Lokurtullye coal is easily approached from, and very little above the level of, the Nerbudda valley.
7. *Bori Valley.* Thick beds of carbonaceous shale with many threads of coal, as seen at out-crop ; it is not workable.
8. *Dumrus Nulla* in the Deinwa valley. Frequently repeated beds of carbonaceous shale with threads of coal : not workable.
9. *Mukakhera Village* (west of Rappa village.) Thick black shale bed with threads and patches of coal : not workable.
10. *Nuzurpur Village.* A few miles north of Meerut, coal occurs 30 feet below the surface, where it was cut in sinking a well; thickness not known, but quality inferior.
11. *Amari Village.* South of the village and from 3 to 4 miles east of Nuzurpur a band of poor shaly coal comes to the surface, 10 to 15 inches thick ; not workable. This may probably be the Nuzurpur seam.
12. *Mahanuddi River*, near Binpar village ; an 18 inch thick band of poor coal is seen, probably not workable.
13. *Johilla River*, near Mulliagora village. A band 20 inches thick is seen accompanied by two 3 inch bands, separated from the main seam and from each other by black micaceous shale. The mineral is pure, light and very bituminous.

Dr. Spilsbury mentions that when he crossed the Johilla he noticed a fragment of coal among the shingle : it may have come from this bed.

All the above mentioned beds belong geologically to the lower Damuda series. They have all been examined by the Survey, and many of them now for the first time described. With respect to such localities as 13, 12, 6, 4 it may be safely asserted that their being all worked with advantage is merely a question of facility of transport. No. 6 may be an exception to the above remark, the coal at its out-crop being as stated, very pyritous. Concerning the localities numbered 1, 2, and 3, there can be no doubt, they are all capable of turning out large supplies of good coal. As to the remaining numbers, the interest attaching to them is more geological than commercial, they are useless save as *possible indications*, and should be regarded as even in this sense very untrustworthy.

All the following localities occur among the upper Damuda beds :

14. *Hurd and Sakur.*

Three seams exist here, of two inches, three inches, and fourteen inches, respectively. The last varies from 14 to 10 inches, dips at an angle of 20°, and is good coal. This locality is described by Col. Ousley ; the beds out-crop in a gorge at the junction of the above named streams, and three miles south of Hutnapur village. They are so situated as to be extremely difficult of access and difficult also to work, so that there is little prospect of their ever being made available as a supply of coal.

15. *Sher River*, near Sehora village : known to Col. Ousley. This out-crop is well situated, but that officer seems to have greatly overrated the value of the coal. Three or perhaps four bands of shaly coal exist from 4 to 6 inches thick, quite useless commercially.

16. *Machiriva River.* At Murpipria village one and a half or two miles above the junction of the above stream with the Sher, coal is seen. (see detailed section page 179) Two seams, 10 inch and 2 feet thick respectively, are exposed ; and the quality of the fuel seems fair. This place is very little elevated above the level of the Nerbudda valley and might be made easily accessible by a road.

17. *Lameta Ghat.*

A small quantity of very poor coal has been obtained near the surface at this place. A pit lately sunk was abandoned on account of the worthless nature of the coal and because the patches even of this, were small in extent, and not continuous. Some trial borings were also made near Jubbulpur in the hope of finding the Lameta ghât bed better than at its out-crop, but no coal was struck.

Note.—With the possible exception of the Machiriva coal, no bed, as yet known to occur among the upper Damuda rocks, offers any prospect of becoming commercially important.

(APPENDIX. B.)

At page 113 a reference has been made to a report bearing on the Iron Ores of the west portion of the Nerbudda valley, submitted by Mr. Oldham to the Government of India in 1856. This report has never been printed and as it refers generally to the subject discussed in the preceding pages, a few extracts will be here given.

Mr. Oldham visited the district about Poonassa and Chandghur in April 1856. At that time the attention of the Hon'ble the Court of Directors of the East India Company had been strongly directed to those districts by the glowing terms in which they had been reported on by the officers of the Bombay, Baroda, and Central Indian Railway, and they had instructed the Bombay Government to despatch some of their own servants to test the truth of these statements; and further had authorized that Government, should these reports appear well founded, to proceed at once to establish works for the manufacture of Iron on a sufficient scale to render it generally and commercially useful.

The reports referred to had been given to the public in No. XIV. of the Selections from the records of the Bombay Government. Of these, the report of Mr. Jacob, who had been deputed by the Railway Company to examine the Nerbudda valley has the most important bearing on this subject. This report appears to have been drawn up by him in April 1854, at Surat, in company with Lieut. Col. Kennedy, Mr. Jacob having previously made a rapid examination of the Nerbudda valley, as far to the east as Jubbulpur. During that visit he had seen most of the localities known to yield Iron and Coal, and then unhesitatingly pronounced in favor of Poonassah and its neighbourhood as the most promising locality for the establishment of Iron works, an immediate commencement of which he urgently recommended.

"Neglecting for the present Mr. Jacob's reasons for selecting Poonassah, a town on the south side of the river, and at a distance of 12 to 14 miles from the Ore pits, as the site of his proposed works, I will briefly describe the circumstances under which the Ore occurs."

"Iron Ore is here found in two forms, 1st, as a gravel or detritus consisting of loose rounded lumps of partially decomposed hæmatitic Iron, which forms irregular beds accumulated in the hollows or depressions of the surface, and 2ndly, as a distinct bed or vein of similar ore, in a solid and undecomposed state. The latter Mr. Jacob did not apparently see. The gravel-like deposits of ore are in several places. Of these, one of the principal is at Chandgurh to which Mr. Jacob refers. Although called the Chandgurh deposit, it is nearly 3 miles from the village of that name. It covers an area of probably altogether one quarter of a mile square, the thickness within that area varying from four or five feet to a mere scattering of loose pebbles over the surface. Its limits are well marked and well known, being confined by a low broken range of small hills in which no traces of this ore occur. Another of these deposits of ore in loose lumps occurs about six or eight miles north and east of these Chandgurh pits, near to the small villages of Bamha and

Nanera, yielding ore of the same quality and being of about equal extent in area. A third area where similar ore, although here not quite so rich, is obtained, lies to the east of the river Tawa, near the old and now abandoned village of Basnia. This deposit is in places thicker than either of the others, being locally so deep as 10 or 11 feet."

"Other smaller deposits occur here and there filling small depressions on the surface, and forming detached areas from which this iron gravel has been partially exhausted. These are numerous, but of no great extent. Those mentioned by Mr. Jacob, as occurring near Poonassa village, and which were opened during his visits, have, I believe, been since abandoned, not proving remunerative."

"In addition to these sources of ore, a regular vein or seam of rich specular iron is worked near to the gravel deposit at Nanera. And this appears to me the most valuable source of ore in the whole district. It is of variable thickness, from 2 feet to 8 or 10, but of fine rich quality, and with very little admixture of any gangue or stony matter."

"The more easily extracted loose ores are preferred by the Natives; their wretched tools and appliances failing to make much impression on the harder and more solid mass. The ore is extracted by little burrowings or holes sunk in the deposits most carelessly constructed and most of which falling in during the rains have to be entirely reopened for the succeeding year's operations. The ore in these deposits has been derived from previously existing beds or veins, which have been broken up, drifted, and sorted, by the action of water, and arranged in regular layers, where the greater specific gravity of this ore, compared with the quartz and other ingredients mixed with it, has led to its deposition. They are, in fact, in all respects analogous in their mode of deposition, arrangement &c., to many deposits of Tin ore, and are nothing more than Stream-Iron-works. Nature having thus already sifted these ores, and removed the greater portion of the extraneous matter, they are necessarily more productive than the same ores freshly extracted and mixed up with veinstone &c., would be. I do not at all doubt that the specimen examined by Mr. Jacob may have yielded 60·4 per cent. of iron, but this is certainly much above the *average* yield of the ore, which would not exceed 55 per cent."

"Mr. Jacob mentions that the river Nerbudda cuts four large veins within the short space of one mile, one of which is 122 feet wide. Accompanying this statement there is no plan or more detailed description to shew where these veins occur, but from the coincidence in measurement and from the absence of any thing even so slightly agreeing with his description in other places, I conclude that he refers to the part of the river Nerbudda immediately above the junction of the river Tawa. In this place, several veins of a siliceous breccia with a ferruginous cement cross the river, the largest of which coincides with the measurement given by Mr. Jacob. If these be the lodes or veins referred to, I have no hesitation in saying, that as practical sources of iron ore, they are utterly useless. That an iron ore of good quality occurs in them is beyond a question; but it is too sparingly distributed in the mass, and the small bunches of it which occur are too few and

too limited in extent, to be worth the expense of extracting; while the rock is itself so intensely hard and intractable, that I am convinced the cost of mining the ore would be ten times the whole value of the metal extracted. To follow up such nests of ore may be remunerative with some of the more valuable metals, but in this case would never pay. No doubt these breccias have yielded portions of the rolled and loose ore now scattered over the surface, to the long continued and economical processes which nature has adopted in wearing down their surfaces, but as a practical source of Iron Ore they are altogether worthless."

"For the extraction of this ore, no rent or tax is paid; the landlords of the district charging a small sum (one rupee) annually for each furnace erected within their limits. Its cost therefore varies principally with the distance to which it has to be conveyed. At Poonassa, a distance of 12 miles, over a tolerable road, but with a bad crossing of the river, (where the ore has all to be taken off the carts, carried in baskets by coolies down the water, there shipped into small boats and on arrival at the other bank, again to be carried up the steep banks by coolies and then reloaded on carts for conveyance to Poonassa) in Poonassa I say, this cost is one rupee for about 7¼ mds. or a little less than 4 rupees or 8 shillings per ton. At Chandgurh, Bankeepulla, and other villages which lie on the same side of the Nerbudda and at a shorter distance from the ore pits, the cost of the ore is of course much less; and I am satisfied that within an average distance of, say, ten miles from the "mines" the ore could be supplied at a mean cost of 4*s.* 0*d.* to 6*s.* 0*d.* per ton."

"I do not see reason to agree with Mr. Jacob in the estimate he forms of the inexhaustible supply of this ore which exists, but I think there is a large amount of very rich, valuable and easily wrought, ores here available. But unfortunately there is by no means the same abundance of fuel for the reduction of this ore. Mr. Jacob says, "the district for miles is dense jungle; the timber is of the highest specific gravity including Undial and stunted teak; it is admirably suited for the manufacture of charcoal, and the supply will last for many years." I must say that the wretched coppice which covers the stony, parched, and poor soil of the country could only have appeared "dense jungle" to an eye quite unused to Indian scenery. There is no part of it which cannot be ridden through with ease. The timber is all small, and the useful or hard wood trees form but a very small proportion of the whole."

"Bearing on this question I may state that the remains of many smelting furnaces may be seen through the country, now abandoned, and abandoned solely because fuel was not obtainable in the vicinity, while the ground all around is covered with trees: trees however of *salee*, which is useless for the furnace.

But the most satisfactory proof of the want of fuel, even for the present demand, will be found in the fact that when a proposition was made to buy up all the Iron made in the district and to make advances to the people to enable them to set up new furnaces, and thus to increase the supply, the offer was declined, and for the simple reason "*that fuel could not be obtained.*"

"There appear to me to be excessively crude notions in the minds of some persons as to the supply of fuel required for such purposes." "Unlimited and dense jungle," "exhaustless supply of wood" &c. &c., are terms constantly used without much examination of the facts. I can only say, that I have now seen much of the densest jungle and most heavily wooded parts of India, in the Terai, in the N. Eastern frontier &c., and I have never seen any place, which, without the strictest conservancy and limitation of supply, could have supplied a couple of blast furnaces for a couple of years, within a circle of 8 to 10 miles from these places. Because the present limited demand does not appear to exhaust or in some places to materially affect the supply, it is hastily concluded that the increased demand might be met also, without considering what the ratio of increase would be."

"Further, for any improved processes of manufacture this demand must and will become concentrated, instead of being, as at present, scattered over an immense area. *Now* each person sets up his furnace wherever circumstances are favorable, and works on until his fuel or his ore becomes exhausted or too costly to be profitable to work, he then removes; and this is no very costly process, when 6 or 8 rupees will pay for the whole of his *plant*."

"To enter into more detail, let us take the district now under consideration. There are at present in "blast" in this district (not including those supplied from Burwye and Kantcot on the west) about 40 small country furnaces. Of these, the furthest apart are in one direction about 22 miles, in another direction about 14, giving an area for the supply of fuel of about 300 square miles; or remembering that the supply of the most distant furnaces is derived from *all* sides, of about 350 square miles in all. The facts I have given above shew very clearly that this area only just meets the demand upon it, at present existing."

"The outturn of each of these furnaces, supposing them to work steadily for 25 days in the month, is not more than 20 maunds of raw iron, or for the entire number (40) not more than 800 maunds, or per week 200 maunds equal to 7¼ tons! Now it would be a very small work which would turn out 100 tons of raw iron per week, or which would, with the same ratio of consumption as now exists, require very nearly 14 *times the supply of fuel now used.* Again, these native furnaces never, at the best, work for more than 7 months in the year, while any improved system of manufacture should necessarily be constant. This would of course add to the demand in the proportion of 12 to 7 about three-fourths more than is stated above, or in all a supply of fuel fully 24 times that now existing would be required. It is also obvious that however useful this supply may be, scattered over its area of 350 square miles, while the demand is equally scattered, a large portion of this would be too expensive to bring to any one spot profitably."

"This calculation is, as I have stated, based on the assumption that the ratio of fuel consumed to the metal produced should be the same as now is the case. I am fully aware however that the present consumption is extremely wasteful,

so much so, as to be scarcely credible to those who have not seen it. I am also fully aware that the mode now in use for the manufacture of charcoal here as elsewhere through the country, is nothing more than an ingenious device for obtaining the smallest possible amount of useful fuel from the largest possible quantity of wood. And for improvement in both these directions I would be prepared to allow for very large deductions from the amount as given above. But even supposing that under improved management these items were reduced three-fourths or by 75 per cent, there would still remain a demand for six times the present amount of fuel, to meet the possibility of producing 100 tons of raw iron per week, a demand, from the facts I have mentioned, it is obvious the district could not yield."

"The soil is poor; Mr. Jacob says "very barren," and the growth of timber is necessarily slow and stunted, so that, once exhausted, years would elapse before the supply could be renewed. I am therefore fully satisfied, that so far from Mr. Jacob's statements that "the supply would last for many years" being in accordance with the facts, it would not keep a single furnace yielding 100 tons of iron per week in blast for many months. I would add that I feel equally satisfied that, if Mr. Jacob were writing his report in 1856 instead of 1854 this would be his own statement also, after the experience of the intervening years."

"I believe that this circumstance is perfectly conclusive against any attempt to establish iron works on a large scale at, or near Poonassa."

"But while thus compelled to differ from Mr. Jacob's views, or rather from what were his views in 1854, the fact still remains that there is a large amount of rich and valuable ores of Iron, which, were fuel accessible, could be easily economized. And it will be worth while to consider whether this rich ore could not with profit be conveyed to some other locality, where the circumstances are more favorable."

"I think it unnecessary to discuss the reasons given by Mr. Jacob to Lieut. Col. Kennedy for selecting Poonassa They appear to me to be without force, and I am disposed to think that a point on the south side of the river Nerbudda was fixed upon with a view rather to the then contemplated branch of the Railroad up the valley, than simply from a consideration of the circumstances of the locality. Had the present project of a branch on the north side of the river from Baroda to Indore been then thought of, I cannot but fancy that a very different locality might have been selected. The fact of Poonassa being in British territory while the north side of the river is in native territory, appears to me to be of very trivial importance. I could not ascertain, I confess, that there would be any material distinction bearing on the value of such works, between the two. And as to the proximity of the required flux (limestone) there are few points in the valley of the Nerbudda, between this and Jubbulpur, where from the abundance of limestone it could not be procured at a reasonable rate."

"I would add to this information regarding the Iron deposits of Chandgurh a few details as to the cost at which it is at present manufactured. The establish-

ment of several furnaces which are worked by convict labor in the jail at Poonassa, and the effective and hearty aid given me by Lieut. R. H. Keatinge, under whose very able, zealous, and intelligent, management the district is, have enabled me to obtain this with greater accuracy than I should otherwise have been able to do. The native smelters never calculate their expense and are quite unable to give trustworthy information at once. It is only by a long continued series of cross examinations, returning again and again to the same point, that the real facts can be arrived at. I have however done this and compared the results thus arrived at, with the results obtained from the accurately kept accounts of the workings in the jail, and feel confident that I have arrived at as fair an average as possible."

"To construct a furnace in the first instance costs about Rs. 1-14 or about 3 shillings and nine pence. This with the ordinary repairs will last 2 or 3 years. If a shed for this be erected, the cost will be about 4 rupees more. A pair of bellows of the ordinary Indian construction made of large goat skins, with the common hand-closing valve or opening, cost 5 or 6 rupees: so that the whole establishment required for the working of one of these furnaces will not require a first outlay of more than 12 rupees, which will last for 3 years, or does not involve a daily expenditure of more than a few pice. For the daily work of one of these furnaces, the cost of the materials necessarily varies with the locality. At the jail at Poonassa it is as follows:

	R.	*A.*	*P.*	
Ore, ...	0	10	0	about 180 seers
Charcoal, ...	0	10	0	
Wood, ...	0	4	0	
Cow-dung, ...	0	0	3	
Earth, straw, &c. for tuyeres and repairs,	0	3	3	
	1	11	6	total

cost of materials for an average produce of 48 seers of raw iron. This is the average cost and average return as obtained from carefully weighing the materials used in three furnaces, and the iron produced, and then comparing these results with the monthly outturn and monthly cost of the six furnaces which are kept constantly at work. The cost of the materials in the district is less, but the produce is also less, so that this may be taken as a fair average. To this cost must be added the labor of the men employed, namely, two at 2 annas each, or 4 annas per day, giving a total cost of 1-15-6. To this we may add 0-0-6 for wear and tear of furnace, bellows, &c., making a total of 2 rupees for 48 seers of cutcha Iron, or exactly 5 rupees for 3 maunds. Now this is the price at which cutcha Iron is sold in the country, so that the margin for profit is extremely small, and is produced solely by the occasionally larger produce obtained, and by the saving in labor resulting from the employment of women and children in the district, not in the jail."

"In the reduction of the *cutcha* Iron, a loss of one half its weight is incurred,

the pulla or 3 maunds of *cutcha* Iron only giving 1½ maund of *pucka* or useable Iron. For the reduction of this quantity there is required of

	R.	A.	P.
Charcoal, ...	0	6	0
1 head workman, ...	0	6	0
6 workmen, @ 2 annas each,	0	12	0
	1	8	0

or a total of one rupee eight annas for the cleaning of 1½ maund of Iron. This *pucka* Iron however sells for 14 rupees 4 annas per pulla or 3 maunds, having cost as above 13 rupees (*viz.* 6 maunds of cutcha Iron=10 rupees and cost of reduction 3 rupees=13 rupees). This is the price at which the Iron manufactured in the jail is sold (4 rupees 12 annas) per maund, that manufactured in the district can be purchased for 12 rupees the pulla. Lieut. Keatinge has introduced the use of a heavy tilt hammer, worked by the feet, which has necessarily improved the quality of the Iron, by more thoroughly expressing the slag, than could be done by the use of small hand hammers. The reduction of the raw or *cutcha* Iron, to the more pure, or *pucka* condition is therefore a more profitable process than the original smelting, and I believe it was with a view to taking greater advantage of this that the proposition, I have alluded to above, to extend the manufacture of the *cutcha* Iron by setting up new furnaces was made."

"The *pucka* Iron again loses ¼ of its own weight in being wrought up into tools &c."

"The present cost therefore of the "cutcha" Iron or the first produce of the smelting of the ore is 5 rupees for 3 maunds, or about £4-12 per ton. Of the "pucka" Iron the present price is about £12-15 per ton. And it is certain that these barely yield a profit in the manufacture as at present carried on."

"It is equally certain that, at these prices, imported English Iron will command the market, from its greater purity, and the very greatly more convenient forms in which it is procurable. Bolts, bars, plates of every size which may be required can be had ready prepared, while the native Iron involves great trouble and time in bringing it into the same forms. With a view to obviate this objection Lieut Keatinge is I believe most anxious to introduce a small rolling machine, and practically to test the applicability of this Iron to rolling purposes. The Iron is of *excellent* quality, though soft, and I have no doubt could be easily wrought, and certainly the experiment could not easily be placed in more competent hands, than in those of Lieut. Keatinge, who has already devoted much time and attention to the improvement of this manufacture within his district."

Dated, April 14th 1856.

Geologically considered the Iron ores of the Nerbudda Valley may be conveniently separated into four groups.

1. The detrital ores or surface accumulations of gravel and shingle formed of fragments of Iron ore with ferruginous sand and clay.

2. The Iron clay bands of the Damuda and Mahadeva Sandstones, sometimes though rarely smelted.
3. The ores extracted from among the beds of the crystalline rocks, which are interstratified with the quartzite and hornblende schists.
4. The ores which are accumulated along fault lines and which are found enclosing fragments of the nearest beds and filling hollows and cracks among them.

To this last class belong the Jaoli and Agaria mines, as well as those of Omurpani (Tendukhera) and of the Chandgurh country, including Bahin, in all which the vein is worked on, and in some along, the fault line. These are by far the more productive mines: the ore is, chemically, *hydrous* peroxide, though the anhydrous variety exceptionally occurs.

No. 3 is the next in importance, commercially. It includes Gungyo, Lameta and Punagur and other less important mines. As stated, the ore is geologically connected with the old crystalline rocks and more ancient in origin than No. 4, which may have been derived from the decomposed ingredients of these ores which are exclusively anhydrous peroxide.

No. 1 is largely worked in places, as for instance in the Chandgurh and Poonassa country, and may probably be due to the degradation of Nos. 4 and 3.

No. 2 is very rarely worth working, but is fused in a few places in the hills, where the old slag heaps prove that at some former period a greater number of furnaces existed than are now found. The ore is very impure and requires much selection and cleaning.

All future developement of the Iron-producing powers of the country must be of course directed to Nos. 3 and 4.

No. 1 is, on account of the great facility with which it may be extracted, largely used at present as a source of Iron, but is incapable of furnishing a large or constant supply, and No. 2, which for the most part scarcely deserves the name of an ore, is worked exclusively among the hills where the great abundance of fuel offers an inducement to the present smelter.

On the Tertiary and Alluvial deposits of the central portion of the NERBUDDA VALLEY, *by* WM. THEOBALD, JUNR., ESQ., *Geological Survey of India.*

Alluvial deposits.

THE extensive series of beds of an alluvial character which constitutes the greater portion of the level ground in the Nerbudda valley has long attracted attention from the numerous remains of Mammalia of both extinct and living types which it has afforded. But though various collectors have successfully devoted themselves to the acquirement of these interesting relics, no detailed account of the beds in which they occur has hitherto been published.

Division of beds.

The beds in question may be divided into two groups, both containing the same species of existing freshwater shells; but between the deposition of which a considerable lapse of time has intervened, as evinced by the extensive denudation to which the lower one has been in many places subjected.

General section of beds.

The following general section exhibits the prevailing lithological aspect of either group, though all the beds are not of equal value, and each and all are subject to local diminution or increase, either from the process of denudation or causes which have regulated and modified locally the original deposition of the beds. To this I shall allude hereafter and I will merely premise that the section here given is not derived from any single spot but intended to convey at a glance the constitution and sequence of these beds in relation to each other; and to exhibit the general lithological characters and arrangement of the strata throughout the entire district.

Ascending section of alluvial deposits in the Nerbudda valley.

Lower group (*a*).

Sandstone and conglomerate, finer towards the top.

Coarse conglomerate.

Stiff reddish clay.

Bones throughout this group.

Upper group (*b*).

Pale brownish alluvium passing upwards into Regur, or the black cotton soil of Western India.

Bones very rare in this group, and these probably derived from the abraded beds of the lower group.

Group (*a*).

In a number of beds of mixed fluviatile, and lacustrine, origin such as these beds are, but little uniformity of mineral character can be expected for any distance even in the same bed, any more than in the accumulations in the channels of existing streams; and we accordingly find that the only bed which is at all continuous and exhibits every where the same aspect, is the reddish yellow clay at the base of the series. This is in many respects a bed of considerable interest, from its apparently lacustrine origin.

It is not often that the base of this bed is cut through by the river, but towards the west, both above and below Hosungabad, it is seen resting on the gently inclined beds of sandstone of the Vindhyan group, which there form the bed of the river, with the intervention only of a thin band of shingly conglomerate, of variable thickness, which everywhere forms the basal member of the group.

Conglomerate at base.

In the bend of the river below Murdanpur this last bed consists of a layer of gravel, from a few inches to a few feet in thickness, containing a few small fragments of bone; but about Bareta, 12 miles above Hosungabad, it assumes the form of a hard conglomerate, containing bones and numerous shells of

Unio and Corbicula and cemented by carbonate of lime. This in some parts is beautifully crystalline and in sufficient quantity to appear to constitute the base of the rock. The thickness is here not seen, but is probably inconsiderable, perhaps not more than 5 or 6 feet.

Reddish yellow clay.

Resting on this conglomerate occurs the clay before alluded to, which, wherever seen, presents the same uniform aspect, and is in many places the only remnant of the lower group which has escaped denudation, prior to the deposition above it of the upper alluvium and regur.

Its character is that of a stiff fat clay of a deep reddish yellow colour, somewhat mottled on its exposed surface and containing concretions of kunkur, though not so abundantly as do the beds overlying it; also bones and shells, the former very sparingly, the latter more plentifully but locally distributed, so that it generally appears entirely deficient in organic remains.

This clay is well exposed in the banks of the Baru Rewa Nullah, below Garrawara, where it is covered by the alluvium of the upper group, but the unconformity of the two deposits cannot here be clearly made out owing to the complete parallelism of the beds of either group, and the regularity with which the beds of the lower group have been denuded and removed. In one or two places however little channels may be noticed, furrowed in the surface of the reddish clay, which sufficiently prove the extent of denudation to which the lower group had been subjected previously to the deposition of the upper.

Section at Devacachar.

The clearest section exhibiting the unconformity of the two groups is seen in the bank of the Sher river, at its junction with the Omer near the village of Devacachar, of which the following is a sketch, the horizontal distance being slightly curtailed.

Fig. 1. Bank of stream near Devacachar, Nerbudda Valley.

a. Reddish yellow clay; *b*. Sand and gravels; lower group: *c*. Fine alluvium; upper group.

In the above section the unconformity of the upper and lower group is clearly seen, but such cases are of rare occurrence, though a close examination will often reveal similar, though rarely such well marked and striking, cases as the above.

Along the course of the Omer and Sher rivers, this clay is often seen 20 feet thick and its greatest thickness is probably not under 30 feet; but in some places it does not attain more than half the last mentioned amount, as in the following section near Dongagaon, (17 miles above Sagwân Ghât), where both the lower and upper group are fairly developed together, which is not usually the case.

Section at Dongagaon.

Section near Dongagaon (ascending).

Group *a*.

1	Very coarse conglomerate with large boulders, and remains of *Elephas, &c.*, a few feet, ...	
2	Reddish yellow clay with kunkur,...	15
3	Loose sands and gravels very false bedded with courses of hard conglomerate and a few bones throughout, ...	35
	Group *b*.	
4	Pale brownish alluvium and regur, ...	35
		85

The red clay occurs along the entire course of the Nerbudda as far as examined, and to judge from published accounts, in all probability extends to the sea, and though dipping and rising at intervals along the

river may, on the whole, be regarded as absolutely horizontal, the trifling undulations above alluded to, being the result of the method of its original deposition rather than of any subsequent elevation or disturbance.

Extent of clay.

The lateral extension of this clay in a North and South direction so far as actually seen, is at present inconsiderable. It mostly follows the main trough of the Nerbudda and some of its most important tributaries, though its actual boundary is difficult to determine owing to the fact of its being covered over by the more recent deposits. These are seldom cut through by the minor streams at any distance back from the Nerbudda, and consequently they effectually conceal the bed in question, but there is little reason to doubt that formerly, along with the other beds of the group, it filled up the entire level portion of what now constitutes the Nerbudda valley.

The character of this bed is essentially lacustrine, and it was probably deposited at a period when the present valley of the Nerbudda was occupied by a series of lakes connected more or less intimately with each other, and fed by a slowly flowing river down which clayey sediment and occasionally carcases of various animals were carried, and distributed in a gradual and uniform manner over a considerable breadth of country.

No other supposition seems adequate to account for the uniform appearance and absence of stratification which this clay every where exhibits, though the upper beds, from their coarser character, were accumulated under different conditions and in a more rapid and irregular manner.

Dr. Impey appears to have received the same impression touching the former lacustrine conditions of the Nerbudda valley, for at page 8 of his Memoir on the valley, in the Bombay Government Records No. XIV. new series, he thus expresses himself—"The true valley of the Nerbudda may therefore be confined to the undulating *districts of the basins which have evidently been marine lakes.*"

The shells, however, which occur in this deposit, distinctly and in the most unquestionable manner prove its fresh-water origin; that is as far down as Hosungabad; and there is no reason to suppose that any portion of the bed was deposited under different conditions: not that the intrusion of brackish or salt water into the valley towards its mouth is itself an improbability, but from the absence of all proofs countenancing such a supposition. Near Hâtnora, Birmân Ghât, and other spots, this red clay contains great numbers of fluviatile shells of species now living in the district, among which the Uniones are conspicuous from their size and numbers. Where these shells are most abundant, the clay often assumes a dark tint, probably from the amount of decayed animal matter contained in it. The shells are invariably perfect as when alive, the bivalves being united, the hinge ligament entire, and the inside frequently empty or merely partially occupied with a little dark clay, chiefly the residue of the animal; or merely lined with a coating of calcareous spar.

Shells in the lower group.

The following shells* have been noticed in the lower group, and also occur throughout the upper one as well, being equally abundant in either, though usually locally congregated, often in prodigious numbers, both in the clay, and arenaceous beds.

GASTEROPODA.

Melaniadæ.

Melania tuberculata Müll. Not rare

Rather small, and with the apex entire.

Paludinidæ.

Paludina Bengalensis Lam. Very common.

This shell often occurs of a large size, and an impoverished variety is not rare.

* The shells here enumerated have been identified by aid of a collection authentically named by Mr. Benson, whose extensive acquaintance with Indian shells is well known.

Paludina melanostoma. B. Not uncommon.

This shell is not easily separable in a fossil state from the smaller varieties of the last. It is stouter and rounder in the whorls than is generally the case with P. Bengalensis.

Bithinia cerameopoma B. Not rare.

Bithinia pulchella B. Not rare.

Helicidæ.

Bulimus insularis Eh. (B. pullus, Gray). Rare.

Occasionally met with in the reddish clay.

Limnæidæ.

Limnæa sp. Not common.

A small pointed shell of the type of *L. acuminata.* Desh.

Planorbis Coromandelicus Fab. Very rare.

But one or two specimens noticed.

Planorbis convexiusculus B. Rare.

CONCHIFERA.

Unionidæ.

Unio marginalis Lam. Common.

This shell occurs very fine, chiefly in the clay.

Unio corrugatus Lam. Common.

This shell is very abundant and fine: it exhibits a marked variety with a greater transverse breadth across the umbones, which gives it a more triangular appearance than the normal shell. The same variety also exists with the ordinary form in the Nerbudda at present.

Unio cæruleus, Lea. Common.

This shell often occurs extremely fine in the clay, while in the gravelly beds a dwarfed variety is met with not more than half the size of specimens from the clay.

Cycladidæ.

Corbicula cor. Sow. Very common.

Two varieties of this shell occur commonly. One, the usual form,

the other having a greater transverse breadth than the last and presenting in consequence a more triangular aspect. A few shells of a third and larger variety occur about Birmân Ghât but can hardly be separated specifically from the smaller and more common form.

The annexed table exhibits the relative size of the most conspicuous shells of these beds contrasted with recent examples of the same shells the measurements being in inches and decimals, first across the long axis of the shell, secondly across the short axis, and thirdly the thickness of bivalves, or in univalves the maximum diameter of the body whorl.

	Fossil.	Recent.
Melania tuberculata. Müll,		
Apex entire, whorls 11, ...	1.17	1.17
	0.34	0.35
Very fine from Bombay, ...		1.40
Apical whorl eroded, whorls 10, ...		0.41
Paludina Bengalensis. Lam.,		
Large, ...	1.57	1.40
	1.15	0.98
Very large, from Benares, ...		2.05
		1.40
Paludina melanostoma. B., ...	1.15	1.04
	0.90	0.80
Unio marginalis. Lam., ...	4.12	3.63
	1.84	1.75
	1.25	1.21
Unio corrguatus. Lam, Normal shape, ...	2.37	2.50
	1.60	1.75
	1.10	1.30
Nerbudda variety, ...	2.20	1.80
	1.80	1.62
	1.40	1.20
Unio cœruleus. Lea, ... large. ...	2.49	1.96
	1.25	0.90
	1.00	0.86
small. ...	1.49	
	0.80	
	0.50	
Corbicula cor. Sow. ... ... large ...	1.00	0.85
	1.00	0.71
	0.70	0.48
Large var : from Birmân Ghât, ...	1.35	
	1.20	
	0.85	

The only *land* shell noticed in the lower group was ***Bulimus insularis*** Ehr. which occurs sparingly in the reddish clay, at the mouth of the Baru-Rewa nulla near Sagwan Ghât. From this limited distribution

it would seem at a former period to have been less plentiful than at present, as it now is extremely common throughout Central India and the Punjab, and ranges even to Burma and the Red Sea.

In the upper group however a few recent species occur which have not been *noticed* in the lower, though they very possibly occur in it as well; among them *Helix asperella* Pfr. This shell is extremely rare in a living state in the valley at present, and but one specimen was found fossil, but it becomes more plentiful towards the west, in Kattiwar, where it also occurs fossil in beds of apparently the same age as the lower group of the Nerbudda, but of marine origin (*a*).

I will here add for the sake of comparison a list of shells noticed by me, within the drainage area of the Nerbudda, which will be found to include most of the species of common occurrence in Bengal.

Land Shells.

Cyclotus subdiscoideus. Sow.
Bulimus Abyssinicus. Rüpp.
,, cœnopictus. Hutton.
,, insularis. Ehr.
,, punctatus. Anton.
,, gracilis. Hutton.
Boysia Bensoni Pfr.
Succinea vitrea. Pfr.
,, crassiuscula. B.
Pupa bicolor. Hutton.
,, planyunculus. B.
,, diploos. B.
,, bathyodon.
Achatina scutellus. B.
Helix asperella. Pfr.
,, unicincta. B.
,, bullata.

Fresh water Shells.

Corbicula cor. Sow.
Unio marginalis. Lam.
,, corrugatus. Lam.
,, cœruleus. Lea.
Melania tuberculata Müll.
,, lirata B,
,, spinulosa. Lam.
Lymnæa luteola. Lam.
,, acuminata. Lam.
Paludina Bengalensis. Lam.
,, melanostoma. B.
Bithinia cerameopoma. B.
,, pulchella.
,,(?) (small indet).
Planorbis Coromandelicus. Fab.
,, compressus. Hutton.
convexiusculus. Ben.
Ancylus verruca. Ben.

In contrasting the shells from this deposit with those found existing at the present day in the district, the rarity or absence of many of the commonest living species is very remarkable.

(*a*) The same bed also contains other existing shells common in the district (Kattiwar) at present, as *Cyclotus subdiscoideus* Sow. *Bulimus insularis* Eh. *B. Punctatus* Anton *Helix fallaciosa* Fer. &c. A detailed description of this bed would be foreign to the present Report, but reference may be made to the Geological Summary by Dr. Carter who has described it under the term miliolite, or as it is commonly known at Bombay, Pore-Bunder Stone, from the port whence it is shipped for importation into Bombay.

Planorbis Coromandelicus for instance is perhaps one of the commonest shells in India, and yet only one or two specimens have been noticed in the beds of the lower group. *Melania lirata.* B. *M. variabilis.* B. and *M. spinulosa.* Lam; all common living shells in Bengal, are either so rare as to have escaped detection, or are wanting in these beds altogether, though their congener (*M. tuberculata.* Müll) occurs fossil plentifully enough.

These instances suffice to point out the difference between the fluviatile mollusca of the present epoch and those which existed as cotemporaries of the Hexaprotodon. This difference consists in the greater number of specific forms now living, which preponderance is not compensated for by the occurrence of any extinct forms in the lower group, from which *no single species has been obtained which is not abundant in a living state*: and though some shells will doubtless have hereafter to be added to the list of fossil species, yet there seems no reason to suppose that any such additions will invalidate the general conclusions above arrived at.

Sands and Gravels.

Above the clay I have been last describing, occur numerous beds of sand and gravel, of which no one bed is of sufficient importance to need special notice. These sands and gravels are usually loose and incoherent, though often bound together by calcareous infiltration into a very hard sandstone or conglomerate.

Thickness of beds.

In consequence of extensive denudation which this lower group has undergone previously to the deposition of the upper beds, the former thickness of these gravels cannot now be ascertained, but they not unfrequently attain a thickness of 20 feet and upwards, especially towards the east.

Above and below Hosungabad, they occur but sparingly, having been *nearly entirely* removed by denudation; in that direction patches only remaining here and there, as at the mouth of the Tawa nulla above

Hosungabad, which circumstance accounts for the rarity of fossil bones to the westward, as it is in these gravel beds they most plentifully occur.

I shall now briefly enumerate the spots at which bones are most frequently met with; though wherever these gravels are exposed, bones to a greater or less extent may be confidently looked for.

Bone localities.

Commencing at the east, the first spot where bones occur at all plentifully is near the village of Darticachar, a few miles above Jhansi Ghat, where, besides a number of indeterminable bones, sundry teeth and bones, mostly in fragments, were met with, of *Elephas*, *Bos*, *Equus* and *Trionyx*: Chelonian remains occurring very sparingly throughout the group. Below this as far as the junction of the Hiran Nuddi with the Nerbudda, very few fossils were noticed, probably from the ground having been too often and well explored by former collectors.

Kymori.

Along the course of the Hiran Nuddi these ossiferous beds are rarely seen, the banks usually consisting of the upper alluvium. Below the village of Kymori, however, a small patch of sands and conglomerate occurs, from which I obtained several bones of Ruminants and the perfect lower jaw of a large *Hippopotamus (Tetraprotodon?)* but which was unfortunately in too friable a state to remove entire.

Below the Hiran Nuddi fossils are not numerous till near Sagwân Ghât at the junction of the Baru-Rewa Nuddi with the Nerbudda.

Between this point and Birmân Ghât fossils occur not unfrequently, but the locality has been too well known and explored to yield many novel remains of interest for the present.

Patera.

Above the village of Patera I obtained a portion of the molar of a Porcupine and a lower jaw of some large animal, differing from an ordinary Ruminant jaw, and

bearing some resemblance to that of a species of *Palæotherium*, though from the hard character of the matrix and the fragility of the jaw little could be made out regarding it.

Just below Patera I found a small piece of fossil wood not two inches in length in the reddish clay, the only piece of fossil wood throughout these beds which did not appear to have been rolled, for though fossil wood is not rare, all the pieces met with have more or less the appearance of having been rolled and derived from some older group. (Mahadeva?).

Omeria and Deva-cachar.

Near the villages of Omeria and Deva-cachar situated respectively on the Omer and Sher rivers, fossils would seem to be numerous and I there procured numerous remains of *Elephas, Bos, Bubalus, Equus, Hippopotamus,* (*both Hexaprotodon and Tetraprotodon*) *Rhinoceros* (horn), *Axis, Rusa* (or remains of cervidæ of corresponding size), and *Trionyx*.—Below this locality the remains of Hippopotamidæ become very scarce, and they seem to occur most numerously along the course of the Omer and Sher rivers.

Near the village of Omeria the following section occurs (ascending),—

Reddish yellow clay (seen about), ... feet	20
Loose gravel with boulders and teeth of Elephas, Tetraprotodon &c. also Corbicula cor, Unio corrugatus, marginalis, and cæruleus, ...	5
Sands and conglomerates loosely aggregated, with plates of Trionyx, Uniones, Corbicula and Paludina Bengalensis, ...	20
Upper alluvium, and regur, ...	30
	75

About 12 miles below Birman Ghât near the village of Bilthari I obtained the nearly perfect tusk of a large Elephant, probably *Elephas*

ganesa, embedded in the reddish clay which orginally could not have measured much less than 12 feet. A portion had been destroyed by projecting above the clay, and the whole was so friable that it broke in pieces in an attempt being made to remove it. Several pieces however were got out sufficiently solid to send down to Calcutta and are now in the Government Geological Museum. From within a yard of the spot a similar tusk (without doubt its fellow) had been removed to Saugor some years since which measured, I was told, 12 feet. The fragment in the museum measures along outer curve 91 inches, greatest circumference 25; circumference where broken off at smaller end 18.

Elephant's tusk in clay.

From the character of the deposit in which these tusks were found, and their close proximity, it is reasonable to infer that they both belonged to the same animal, whose carcase floated about in still water till decomposition loosened the tusks in their sockets and allowed them to subside simultaneously on the spot where they were discovered. No pebbles or drifted materials are ever seen in this clay, and the bones here and there found in it, are probably diffused in the above manner.

Near the villages of Timmeroun and Kelkach numerous bones of Ruminants were procured, and near the former village the lower jaw of an Elephant in its 4th year, the second molar being on the point of being shed and the 3rd molar almost fully protruded.

Timmeroun and Kelkach.

Near Kelkach some well rolled lumps of fossil wood were found (which occurs very rarely in these beds and) which were probably derived from the beds of some older group, either the Mahadeva, or intertrappean, from the "*subtrappean bone bed*" in the former of which fossil wood is abundant, though the fossil wood near Jubbulpur (not the intertrappean Physa bed, but a member of the older Mahadeva group) is very different in appearance from that found near Kelkach.

Crania of Elephas.

Near the village of Patrora the cranium of an Elephant was found resting on the surface of the reddish clay, but surrounded by loose sand, here and there cemented into a hard grit by lime, and far down the river, near Siuri, another head was obtained lying loose in the bed of the river, and seemingly deposited in a similar position to the last.

Both crania seem to belong to *Elephas Namadicus*, Falc.

Moar Domur.

The richest locality however was near the village of Moar Domur, where, in addition to a number of remains of *Bos*, *Bubalus*, and other Ruminants, I obtained a very fine head of *Bos Namadicus*, Falconer, of which some of the measurements are appended below. Another specimen of interest from the same locality was a very perfect shell of an *Emys*—but remains of Chelonians are generally rare in these beds.

Deer Horns.

Among the remains of Ruminants obtained at several spots occur fragments of horns of *five species* of deer as far as can be conjectured from the broken specimens.

One specimen much resembles the recent *Cervus Davancellii*. The fragment is 5 inches long from the burr where it is broken close off. At 1½ inch it gives off a small bez-antler at right angles—

Girth below the bez-antler,	.....	.....	6¼ inches.
Ditto of ditto	.....	.....	4 „

Of the second species there is also only a single fragment. It is 5 inches in length, smooth and circular, and gives off a small bez-antler close to the burr: it nearly coincides with the horn of the common fallow deer, but is less curved—

Girth at base above burr,	.....	.....	5½ inches.
Ditto where broken off,	.....	.....	3¾ „

A third species is represented by 2 fragments of the long cores similar to those of the Muntjac (Styloceros), which support the horns in that

species. In one specimen the burr is attached, but the horn is broken short off, the other is more mutilated—

Length of pedicle from flattened base,	.....	2½ inches.
Girth beneath burr,	....	4¼ „

The 4th and 5th species are both of the *Rusa* type. The larger species is remarkable for the great angle at which the bez-antler is given off. The more perfect of the specimens measures,

Length,	....	5½ inches.
Do. of bez-antler,	....	3¾ „
Girth at burr,	....	8¼ „
Girth above bez-antler,	....	7½ „
Do. of bez-antler,	....	5½ „
Do do where broken,	....	3½ „
Angle formed by bez-antler,	....	125°

The only fragment of the smaller species is rather flattened but too imperfect to afford much ground for comparison.

The measurements now given in the accompanying table will shew the general dimensions and proportions of a very noble specimen of *Bos Namadicus*, compared with crania of *Bos primigenius* and *Bubalus palæindicus* of which two imperfect crania have been obtained from the eastern portion of the valley.

In the Museum of the Asiatic Society there is in addition a single horn core of a bovine, which from its great massiveness, Dr. Falconer regards as distinct from either *B. Namadicus or B. palæindicus*. This specimen is No. 30, from the Nerbudda, of Dr. Falconer's catalogue. (*a*)

Its dimensions are	ft.	inches.
Girth 5 inches from base, ...	1	7
Length along outer curve, ...	3	8
Girth at tip where broken off, ...	0	3

(*a*) "Catalogue of the Fossil Remains of Vertebrata from the Sewalik Hills, &c., &c.," in the Museum of the Asiatic Society of Bengal, Calcutta, 1859.

We would give it provisionally the name of *Bos Falconerianus.*

	Bos primigenius	Bos Namadicus.	Bubalus palæindicus.
Breadth between orbits, ... (inches).....	*13¼	9½	10¼
Breadth between horn cores, ...	....	9	7½
Central point between orbits to vertex, ...	.....	11¾	11¼
Vertex to orbit (upper part,)	13	11⅞	12¼
Breadth of cranium between horn cores, ...	10½	10¼	7½
Horn cores, lower edge to orbits, ...	.....	5⅞	2½
Length of horn cores, ... (in B. Namadicus 3 inches are added for broken tips,)	42	36	....
Circumference of cores at base, ...	*18¾	13¼	19¾
Tip to tip of horns: (allowing for broken points,)	.....	37½	. .....
Tip to vertex, ...	*26	32	.....
Diameters of horn core 9 inches from base, ...	....	4⅛+⅛	6¼+3¾
Width of cranium above occipital condyles, ...	....	9	11½
Width of occipital condyles, ... (greatest,) ...	....	4½	6¼

Below the last locality few fine fossils occur, but at the junction of the Tawa nulla with the Nerbudda above Hosungabad a few remains of Bovines were found with a few teeth of Equus, in a small patch of gravelly conglomerate, beneath the village of Magaria, which was the lowest spot at which such remains are at all numerous. A few bones have been found at Hosungabad in sinking wells but below that merely a few splinters have been met with.

Fossils rare below Hosungabad.

From the list of localities at which fossil bones more usually occur, it will be seen that the ossiferous beds are mostly confined to the immediate neighbourhood of the Nerbudda. They doubtless in many parts cover a large area beneath the upper alluvium, but it is only the Nerbudda and its main tributaries, whose channels are sufficiently deeply excavated to expose a fair section of these beds.

Causes of the trifling extent of the ossiferous beds.

It is far more usual at any distance from the Nerbudda to find the

* From a second specimen, vide Owen's British Fossil Mammalia, Page 496.

reddish clay alone, immediately supporting the gravels and alluvium of the upper group, the intervening ossiferous beds having in the vast majority of cases been largely denuded, or entirely swept away, save only along a narrow area along the central trough of the valley.

The following is a brief summary of the vertebrate remains discovered in the valley.

Elephas Ganesa.
Namadicus.
Hysudricus (?).
insignis,
Rhinoceros (horn).
Sus.
Hippopotamus (Tetrapotodon) palæindicus.
Do. (Hexaprotodon) Sivalensis.
Equus.
Bubalus palæindicus.
Bos Namadicus.
„ Falconerianus. MS.
Cervus, allied to Dama vulgaris.
Do. do. Cervus Davancellii.
Do. do. Styloceros ?
Rusa ? sp.
Axis ? sp.
Mus.
Hystrix.

Reptilia.

Trionyx.
Emys Namadicus. MS.

Group (b).

This group, which covers a far more extensive area than the last, consists of irregular beds of shingle, sands and conglomerates, passing upwards into a thick deposit of pale brownish coloured alluvium: the upper portion of which merges insensibly into a black soil identical with the Regur so widely spread over Western India.

Thickness of the upper group.

The thickness of this group is not inferior to that of the last, but the development of the coarser beds at the base of the series is very variable and seems greatly influenced by the amount of denudation the lower group has experienced as when that has been inconsiderable the coarser beds of group (*b*) are not met with, and the lower group immediately supports the upper alluvium, but where on the contrary the lower group has been largely denuded, as along the sides of the valley, there the course shingly bottom beds are well represented and often attain a thickness of 30 or 40 feet.

The alluvium, however, and Regur, is less capriciously distributed and averages upwards of 20 feet, though in many places the Regur has been entirely removed by atmospheric causes at present in action, which during every monsoon carry away an enormous quantity from the flat land bordering the Nerbudda, which loss is to some extent made good to the cultivator or to speak more correctly to the productive resources of the country by the deposit of rich silt which the river on falling deposits on its bank and within the embouchure of every creek and nulla flowing into it.

The old bed of the river above Narainpur affords an illustration of the extreme richness of this river silt, and produces a wheat crop of unsurpassed luxuriance.

The lowest bed in this group is usually a conglomerate which varies according to the nature of the rocks in the vicinity. Along the north side of the valley it is chiefly composed of partially rounded fragments of sandstone, the debris of the Vindhyan escarpment.

At a greater distance from the hill its more usual form is that of a coarse gravel, derived from the sands and conglomerate of the lower group, and containing, not rarely, fragments of bones derived from those beds: whilst along the south side of the valley it consists of sheets of shingle and boulders entirely derived from the Trap, schists, and other rocks constituting the hills in that quarter. These enormous accumulations of shingle often 30 to 40 feet in thickness are well exhibited in the neighbourhood of Barkhera on the Sher nuddi near Mopani, and in the stream near Lokurtullye, 38 miles south west from Hosungabad. These shingly accumulations are nowhere seen in the centre of the valley and are chiefly met with where the larger streams issue from the hills which bound the valley to the south, and through whose agency they would seem in a great measure to have been formed, when these streams ran at a different level from that they now have.

Rarity of fossil bones in the upper group.

In the bed of the Bikampur nulla, which flows into the Nerbudda above Jhansi Ghât, I found the rib of an Elephant at the bottom of a bed of coarse shingle consisting of little besides Trap boulders, and but a few feet above the reddish yellow clay of the lower group on which they rest.

A few other fossils have been noticed in these beds but such are extremely rare and are probably derived from beds of the lower group.

In the centre of the valley the lower beds of this upper group usually consist of sands and gravels often cemented into a compact stone by lime, and passing upwards into fine alluvium and regur. These beds are scarcely distinguishable from those of the lower group, the only distinction often being that, whereas bones are rarely altogether wanting in the sands of the one, they are very rarely indeed present in those of the other. The same shells however, which occur in the lower, range equally through the upper, and the alluvium in some places is quite crammed with shells of *Paludina Bengalensis*. In the regur, however, shells

are never seen, perhaps owing in part to its great permeability, but mainly no doubt to the altered conditions under which it was accumulated.

Regur or Black Cotton soil of western India.

With regard to the origin of regur no one who has examined any portion of the Trap area in the vicinity of the Nerbudda can entertain a doubt, any more than regarding the origin of the Trap pebbles so plentifully distributed over the valley. It is apparently a deposit derived from the decomposition of Trap rocks. Though perhaps modified to some extent in different quarters by local conditions and the varied and mixed composition and characters of the rocks in the vicinity, yet, whenever a sufficient expanse of level ground occurs, within or near the Trap area, to permit of its accumulation, there do we find regur under conditions which clearly point out its origin from the decaying Trap rocks surrounding it.*

Pebbles in the Regur.

The only pebbles ever met with in the regur, not of purely adventitious origin are agates, quartz and zeolites such as are contained in the amygdaloidal portion of the Trap rocks in the neighbourhood.

* Mr. Theobald alone is responsible for this opinion.

On the Geological relations, and probable Geological age, of the several systems of Rocks in Central India and Bengal, by THOMAS OLDHAM, L. L. D., F. R. S., &c. &c., *Superintendent of the Geological Survey of India.*

IN the valuable reports which have been given in the preceding pages, the authors have confined themselves strictly to descriptive accounts of the physical relations and general structure of the several groups of rocks to which their memoirs relate; in few cases adding any notice of their fossil contents, or discussing the value of these, as bearing on the question of their geological age. There is, in truth, much good reason why such a plan should be adopted, when we consider how much has yet to be determined regarding even the succession in time of these deposits. It is scarcely necessary to insist here on the impossibility of arriving at any satisfactory conclusions as to the relative age, or in other words, the successive appearance of different forms of organic life, when ignorant of the successive order in which the rocks containing such organic remains were formed. And further, valuable as fossil evidence is known to be, in countries intimately connected where a widely spread induction has enabled careful and detailed classifications to be introduced, this evidence loses greatly in its clearness, when it is necessary to apply the results to far distant and very differently circumstanced localities. In such instances, as might naturally be anticipated, minute distinctions often cease to be applicable, although, at the same time, nothing may be found to invalidate the wider groupings. Details of physical structure *must*, therefore, be thoroughly made out in every new country before we can admit the importance of any variations in organic remains, or seek to build on apparent resemblances or analogies, or even on isolated cases of identity of form, conclusions as to the relative ages of the rocks containing these relics of former life.

It must in all such reasonings never be forgotten that we do know, and could know, nothing whatever as to the successive changes in the forms of organic life at successive periods in time, if we had not been

able to prove most clearly and conclusively, from other evidence, the fact of this succession in time. But, however unquestioned this fact may be in one locality, an attempt hastily to apply it to all others would be simply to revert to the false reasoning which, in the earlier history of our Science, so materially impeded its progress. If we seek justly to compare one series with another, we *must* first ascertain what is actually the succession of the formations in each case. We can then, but not till then, compare these formations one with the other, and can ascertain whether the changes in one locality correspond with those in the other, we may thus have it in our power to establish some common geological horizon, some common date in time, from which we may reason out geological epochs common to both.

It necessarily follows, from these considerations, that all geological descriptions of detached districts in a new country must unavoidably be at first deficient in those very links, which by uniting the rocks of these districts with the acknowledged succession of rock systems in other and well known countries would give a more general interest to the enquiry.

Further, the laws of distribution of fossil forms of life, so far as these laws are applicable to the countries in which we are working, are not as yet so well known, that we can safely reason from the occurrence of any particular forms, as compared with their occurrence in other lands at opposite sides of the globe, to any sound conclusions as to the positive epoch of the beds in which they may be found. The system of the rock-masses acknowledged in European geology, and the succession in which these have been formed, may be well known, and the applicability of the same general classification to other countries lying comparatively near on the Earth's surface may be well established, but there still exist vast gaps in the evidence, before these results can be safely generalized. We still want a knowledge of the real equivalents of rock masses, before we can form any true conception of the physical geography, and the organic existence of the surface of our planet, viewed as a whole at the various and successive geological epochs.

Granting even that the remains of organized existence thus found entombed at opposite sides of the globe are truly identical, would this identity prove such a synchronism in the period of the formation of the rocks as to warrant the application of a classification founded on facts observed in far distant lands? Or if we go further and grant that the species although not identical may be representative, can we assert that this fact can be taken as evidence of synchronism? And we must also remember the important fact first distinctly announced by Edward Forbes, that these species or forms, which are thus widely spread in space, are precisely those which are *most* widely spread in time, and are therefore of the least use as evidence of contemporaneity of the beds in which they occur. Under this point of view, it is to every one who looks to the grand generalizations of the geologist, a matter of the most intense interest to establish the true correlation of any given series of rocks in tropical regions with any established group in Europe, and to trace out the differences both in petrological character, and in organic remains, which may coexist with a general resemblance or conformity to an admitted type. From the first commencement of our labors in Bengal, therefore, it has been a steadily pursued object of my wishes, to establish the age of some fixed group of rocks, and thus to determine a definite horizon, or datum line, from which we could either work upwards to more recent deposits, or downwards to more ancient systems. There were many and very conclusive reasons, besides these general considerations, why, if it were possible, the age of the coal-bearing rocks of Bengal, and Central-India should be the first determined. They were, unavoidably, the first to which we were obliged to direct our attention; they were of great thickness, and covered a very large and widely extended area; and they were commercially and economically of infinitely greater importance than other groups. I have therefore steadily kept before me this object, as has been proved by every brief notice which from time to time I published concerning these rocks.

Our earliest efforts were directed to the examination of the Rajmahal hills, to the north of Calcutta. We hoped there, judging from the brief accounts of the district which had been published, to find some fossiliferous bed, into correlation with which we could trace the coal rocks. The result of the examination I shall give in greater detail below. In that district, however, the base of the series is incomplete, and the relation of the upper beds are much complicated and obscured by the intercalation of vast masses of foreign matter, the outpouring of immense flows of volcanic lavas. (*a*)

A subsequent attempt to trace the coal-beds into connexion with the nummulitic rocks of Eastern Bengal only proved that we had there coal certainly, but coal occurring in rocks of a totally different character and of a totally different age from the coal-bearing rocks of Bengal (*b*). A similar attempt to trace their connection in the Sikkim country, at the foot of the Darjiling hills also failed. Subsequently we have endeavoured by a careful investigation of the cretaceous rocks of Southern India to ascertain whether there could be any connection between these most interesting deposits, (the geological era of which is in a general way, well marked) and the coal-bearing rocks: with what success will appear in the sequel. Similarly in Central India the object has never been lost sight of to trace this very extensive, and to Indian geologists this most important and interesting group of rocks, into connexion with some other system of beds, which might afford us better evidence, on which to base our conclusions as to their geological age. For the difficulty did not arise from the fact that these rocks were devoid of the relics of organic life, but that we had not been fortunate enough to find any remains, save those of plants. And we were fully alive to the imperfection of the testimony which such can give. The study of these fossils must at all times be beset with difficulties, not alone depending on the broken and

(*a*) Jour. Asiat. Soc. Bengal, 1854 p. 271.

(*b*) Memoirs of Geological Survey of India, Vol, I, p. 165.

fragmentary condition in which the remains of plants are so generally found, but also from the marked similarity in form of the leaves of widely distinct genera; the great variation in that form which frequently occurs at different stages of growth, or in different parts of the same plant; and from the doubt which must always exist in referring to the same plant different parts (stem, branches, leaves, inflorescence) which occur perhaps in immediate proximity in the same specimen, although not actually joined together.

Notwithstanding all these difficulties, inasmuch as these fossil plants are, up to the present time (February 1860) the only organic evidence which is known to exist in these rocks, we purpose, at present, briefly to state the amount and character of this testimony, and by a careful investigation of its bearings, to see what light it is capable of throwing on the disputed age of the rocks in question. Before entering on the fossil evidence, however, we shall briefly state the successive steps which have led to the establishment of the different systems, or groups, into which we have found it necessary to divide the whole series of the bedded rocks, as described in the preceding papers.

In doing this we shall begin with the lowest group. It will be unnecessary to delay at present for any consideration of the highly metamorphic gneiss, hornblende rock, crystalline limestone, &c., which cover such an immense area in Bengal. It seems highly probable, indeed we may say certain, that sub-division must be introduced among these rocks also (as I have already stated elsewhere) (*a*). We shall, however, omit any discussion of this point now, and pass to the other systems of beds.

Sub-Kymore Group.—In the brief abstract of the labors of the Geological Survey of India, which I submitted to the Asiatic Society of Bengal early in 1856, I mentioned, (*b*) on the authority of Professor H. B. Medlicott, the occurrence, resting immediately on the gneissose rocks of

(*a*) Memoirs Geol. Surv. of India Vol. 1, p. 160.

(*b*) Jour. Asiat. Soc. Bengal, 1856, p. 253.

the Sone Valley, of a group of beds, to which as coming under those beds which constitute the very marked escarpment of the Kymore range, he proposed to apply the name of *Sub-Kymore*. Our knowledge of this group as it occurs in the typical locality is still, I regret exceedingly to say, in the state in which Mr. Medlicott left it, (the state of the country having prevented our return to the district), but the characters, position, and general arrangement of a marked series of beds which extend along the northern face of the table lands of Bundelcund and which, it is highly *probable*, there represent the "Sub-Kymore" rocks of the Sone Valley, are fully given in his paper in the present volume. These rocks as yet have yielded no fossils.

VINDHYAN ROCKS.—Towards the close of the year 1854, it was decided that an examination of the valley of the Nerbudda should be undertaken. And for this purpose my first assistant Mr. Jos. G. Medlicott was deputed. The aid of his brother, Mr. Henry B. Medlicott was also granted. Starting from Mirzapore, the latter made a traverse of the Rewah country, and crossing the river Sone, passed south to the Singrowlie coal-field: the former proceeded to Jubbulpore, and thence passed westwards along the Nerbudda valley. From both of these zealous assistants I received statements of their results in the following year (1855); and both agreed in pointing out the essential distinctions which appeared to characterize the great thickness of sandstones, shales, &c., forming the country of Rewah and Bundelcund; and to separate these rocks, &c., entirely from the sandstones associated with the coal in Bengal, or in the Nerbudda district. To this great group, however, they did not attach any definite name, speaking of it as "the sandstone," or "the Bundelcund table-land sandstone." I visited that district myself in the beginning of 1856, and seeing the justice of the separation already made by the brothers Medlicott, I thought it desirable to give to this very important group of rocks a definite name; and to indicate the sub-divisions into which it appeared possible to classify it. In a very brief summary, therefore, of the results arrived at in the examination of the Central India rocks,

which I had the honor of laying before the Asiatic Society of Bengal in May 1856,(a) I proposed for the entire group the name VINDHYAN, derived from that remarkable range of high ground, called the VINDHYAN hills, which forms such a prominent feature along the northern bank of the Nerbudda river.

It was true, that for the same rocks other names had been previously proposed, and especially by Dr. Carter of Bombay in his valuable "Summary of the Geology of India," but I endeavoured to shew, that inasmuch as this author had based his classification on erroneous views as to the position of these rocks, and erroneous identifications of the various groups, the result of adopting his name would be inevitably to lead to erroneous conclusions: and that it was, therefore, desirable at once to indicate the separation of this group by the adoption of a distinct and separate name. I proposed to adopt the three-fold sub-division which had been, already, given to the great group—and which seemed to be well defined by marked physical features—and I gave to these sub-divisions, names derived from the localities, where they were best seen; from the Kymore range, north of the river Sone; from the Rewah district, and from the Bundair Hill. I took the opportunity at the same time, of intimating the possibility that this three-fold division might hereafter be reduced to a two-fold sub-division.

This was the view urged by Mr. Medlicott, although not adopted by myself.

I desire here, publicly, to correct an error into which I was at that time led, by placing too great reliance on a similarity in mineral or lithological texture. I stated that the Damuda rocks (see below) rested unconformably upon these Vindhyan beds. It will be seen from the valuable report of Mr. Medlicott's labours (above p. 171,) that no case of actual superposition of the two series has as yet been seen; although from other evidence he perfectly agrees with me in the views

(a) Jour. Asiat. Soc. Bengal, Vol. XXV, p. 249.

I then put forward, that the Vindhyan rocks are of more ancient date than the Damuda group.

In the more recent researches of Mr. Henry Medlicott, as given in the present volume (p. 1, &c.,) he has adopted, with some slight alterations in detail, the three fold division proposed by me in 1856. But we must add, that the entire country in which these Vindhyan rocks are typically seen, must be much more carefully examined, and the detail of its structure more fully investigated, before any really trustworthy conclusions can be arrived at. Hitherto the great practical value of the coal deposits and the absolute necessity for ascertaining the limits of their extension, have led to the examination of those rocks especially, and in a great degree, to the exclusion of the others from any systematic survey. And we cannot but anticipate that such detailed investigation will introduce several modifications of our present views.

From this great group no fossil evidence whatever has as yet been obtained. And it is a most strange and remarkable fact, that thousands of feet in thickness of beds of varied mineral character, fine sands, silts, clays, and calcareous deposits, should thus be spread out in continuous but slightly disturbed beds over immense areas; that bed after bed, often to the number of hundreds in succession, should abound with physical proof of the shallowness of the water in which they were deposited; that the mineral texture of the rocks should be precisely that which seems most favorable for the occurrence and preservation of organic remains, and, still, that not a trace of these should yet have been found. (*a*)

The geological epoch of the Vindhyan group is therefore *entirely unknown*, even relatively.

We pass now to the next group.

(*a*) I some years since saw, in the hands of a friend, a broken specimen of a large and distinct *foot print*. This was *said* to have been obtained from the continuation of these rocks, south of Sasseram; but I could not ascertain any thing certain about it.

TALCHEER GROUP.—During the season of 1852-53 Mr. Jos. G. Medlicott, while engaged in the examination of the southern portion of the Rajmahal hills, pointed out to me the occurrence of a small patch of rocks of very peculiar mineral character. Mr. Medlicott described them as being "in material and general constitution unlike anything seen by him before" in the district. All round the bottom of the series was found a coarse conglomerate bed, while with it occurred thin-bedded sandstones and shales. These fine grained sandstones were characterized by the minute state of division to which the ingredients had been reduced, these being felspar and quartz, (chiefly pinkish felspar) while at the same time, these grains remained perfectly undecomposed. The prevalence of this latter mineral gave a pinkish hue to the mass. Associated with these pinkish beds were also blueish shales. The sandstone, which occurred in thin flaky beds, was also noticed as being greatly jointed, and broken up into small angular fragments or polygonal masses.

The character of these beds was very distinctly pointed out, but as it appeared, on further examination, that the area over which they were visible was very small, and their relations to the other overlying beds were confused by the occurrence of trap-dykes, while no fossil could be traced in them to form a guide to their age, no attempt was made to separate them. They were merely noted as peculiar.

During the following year Mr. St. George, at that time attached to the Geological Survey of India, mapped carefully another area of similar rocks, which occur close to Kurmataur, on the next side of the Rajmahal hills. The relations of these rocks were not known to him nor was the district favorable for working them out. They were, however, carefully separated from the other beds, and so mapped.

Towards the close of 1854, while passing across from Monghyr to the great trunk road, on his way to Central India, Mr. Jos. G. Medlicott paid a cursory visit to some small outlying areas of sandstone, which occur in detached localities among the gneiss rocks of the northern and

western portion of Beerbhoom district. In describing these, he directed my attention to the peculiar lithological character of the beds which occur there, and to the fact of their remarkable identity with the beds, which occur at the base of the Ranigunj coal-field, along its northern boundary, (as described by Mr. Williams in his report, published 1850).

The shales which formed the larger portion of the rocks were described (December 1854, manuscript report), as "mudstones, layers of different colours, and slightly varying coarseness of material giving faint indications of the direction and thickness of the original beds;" formed in layers of from 6 inches to 10 feet thick; "divided by at least "three, if not more, planes of jointing, which cut each other at differ- "ent angles, and reduce the rock to a mass of little cubes, as polygonal "fragments, &c. &c., giving to the whole a very characteristic appear- "ance difficult to describe; but, once seen easily recognized." The sandstones also were spoken of as "soft, muddy, micaceous;" sometimes "fine grained, and, at the same time, muddy and passing insensibly into the mud-flags" and "on the other hand, by various gradations into a very coarse conglomerate, with blocks of from 10 to 20 cubic feet in size, which blocks are all fragments of the crystalline rocks around."

In this district, no rocks of a newer epoch occur in connection with these, and the whole was then viewed as a part of the great series to which the coal bearing rocks of Bengal belonged.

In the beginning of 1855, Mr. Henry B. Medlicott, while rapidly examining the Singrowlie coal-field, to the south of Mirzapore in the Rewah country, remarked the peculiar lithological character of the beds at the base of the series seen there (see above page 172) "green mud "which breaks into cubical fragments, and is much traversed by seams "of calcareous matter, principally on the joint surfaces; it often con- "tains pebbles of the old crystalline rocks, and sometimes boulders of "these of considerable size, occasionally weighing many tons." Again, in the section of a pit, he gives "*boulder clay*" "arenaceous lime-

stone" "*boulder clay*" "Sable rubbly clay" "boulders of crystalline rocks," &c.

A few months later, his brother Mr. Jos. G. Medlicott, in a brief report on the coal and iron of the Nerbudda (*a*) speaks of, as the lowest rock of the coal-bearing formation, "a conglomerate of a fine green earthy base "which is slightly calcareous in places, and the pebbles of which are "exclusively derived from old crystalline rocks"—"thick and thin "bedded sandstones which contain bands of pebbles and are alternated "with some beds of greenish micaceous flagstones." Similar conglomerates are noticed in other places, covered by the "typical coal-bearing sandstones," &c., &c.

From these details it will be seen, that whenever the rocks associated with coal had been examined, there was found to occur at their base a set of beds of very peculiar mineral character. These had been noticed by Mr. Williams in his examination of the Damoodah and Adji fields and of the Hazareebagh fields, and by several other observers as stated. Mr. Williams had however failed to observe that there existed a distinct unconformity between these lower beds and the beds associated with coal, with which they were in contact; and in the other localities to which reference has been made above, there either was no possibility of tracing this, in consequence of no newer rocks occurring in superposition on these, as in several places in Bengal, or there appeared to be a local, though not very well marked conformity, as in Central India.

Such was the state of our information when the Messrs. Blanford (who had only arrived in India a short time previously) proceeded to the district of Cuttack in 1855-56. In the district of Talcheer in the tributary mehals of Orissa, they found a series of rocks, identical in mineral composition, and in lithological character, with those we have already referred to above, (but with which they were, of course, unacquainted), and which were described in detail in their valuable report

(*a*) Selections from Records of Government of India, No. X., page 18, &c.

published in 1857 (*a*) as the "boulder bed" "the tesselated sandstone" &c. These beds were here in immediate contact with the beds containing coal: and the pleasure of tracing out in this district the distinct unconformity, which existed between the two groups of beds, was reserved for the brothers Blanford, early in 1856.

In accordance with a well established practice, they gave to this lower group the name *Talcheer*, from the district in which it had first been satisfactorily made out.

This separation once established, has been subsequently proved applicable in all the other districts, and, chiefly through the labours of Mr. W. T. Blanford himself, the districts already noticed on the skirts of the Rajmahal Hills and in Beerbhoom have been recognized as composed of Talcheer rocks: while the unconformity which exists in Orissa between these Talcheer rocks and the Damúda group above, has been proved to exist also in the Burdwan country (by Mr. Blanford himself), and in other places also, as at Kurhurbari (by Mr. Willson.) The group therefore, as was fairly and justly anticipated by its first describers, has proved a most important and valuable sub-division. It is one also of great interest from the remarkable persistency in mineral character which it exhibits over such a widely extended area—stretching from close to the shores of the Bay of Bengal, to far west in the Valley of the Nerbudda. It is also, of intense interest, inasmuch as the peculiar character of one at least of its beds seems to give us a clue to the climatal conditions under which it was formed; and which, if the supposition put forth be well grounded, must have been extremely different from those now obtaining within these tropical regions.

We shall have occasion to add a few words on the age of these rocks further on.

DAMUDA SERIES.—The fact that there occurred in India, resting unconformably upon the rocks, of which we have been just speaking, al-

(*a*) Memoirs Geol Survey of India, Vol. 1, p. 33. &c.

though apparently not separated from them by any great lapse in time, a thick group of sandstones and shales with numerous beds of coal, has been already alluded to. These beds have been long known. They occur largely developed, in the Ranigunj Coal-field, which has for many years been so profitably worked; they were traced, during the season of 1852-53, extending, with interruption, along the whole western face of the Rajmahal Hills. Dr. McClelland had already described them in the detached Coal-field of Kurhurbari. Mr. Williams in the Ramgurh Coal-fields, a short distance to the south of Hazareebagh. They were known to exist in the field of Palamow to the south of the Sone river and in Singrowli, still further to the west. Coal was also known to occur in the Nerbudda valley in several places, and the researches of the brothers Medlicott in 1855-56 had proved the identity of these beds with those of Bengal, from the identity of the organic remains found in them. That there was therefore one great system, or formation, to which the majority at least of the rocks associated with the coals of Bengal and Central India belonged, was established. About the same time, as Mr. Medlicott was so zealously working out the Nerbudda district, the brothers Blanford and Mr. Theobald were engaged in the Talcheer district in Orissa. And here, quite independently of the labours of others, they also established the fact, that the coal beds occurring there were associated with a group of rocks, peculiar in themselves and separated from those above and below them by a distinct physical break. The same conclusion had been arrived at in the examination of the Rajmahal hills, and in the Nerbudda. And for this great group or series I proposed in May 1856, the name of Damūda or Damooda, from the name of the river along the banks of which the most important and the most productive of these Coal-fields, as well as the best known, extends. This field had been very ably examined, and considering the difficulties under which he laboured, very admirably mapped by Mr. Williams in 1848.

Mr. Williams, in his report, separated the whole series into three

sub-divisions. In the lowermost of these groups he had included those beds which more recent research has shewn to belong to the *Talcheer* group. But, independently of this, his classification is a very sound one, and the several successive groups are well marked and distinct

I am as yet quite unprepared to say how far these sub-divisions may be truly represented in other districts in India. Three distinct groups are given by the Messrs. Blanford, as composing this Damūda system in Talcheer (*a*) and in Nagpur also, Messrs. Hislop and Hunter have proposed sub-divisions of the rocks, which they suppose to belong all to one formation. We may, however, safely say that much still remains to be done in the details of the geology of those districts, before any safe attempt can be made at establishing the parallelism of these minor groups.

Upper Damuda.—In the report (*b*) by Mr. Jos. G. Medlicott, given above, it will be seen that he has distinguished from the true Damūda rocks, a series of beds separated from them by a marked break in physical continuity, but still linked to them by a continuance of the same general conditions, or character of the deposits. To these he has given the name *Upper Damuda.*

* The valued labours of my colleague Mr. William T. Blanford, who is at present engaged in the re-examination of this important Coal-field, have proved the existence of an unconformity, or of a physical break between each of these sub-divisions. So far as the fossil evidence has as yet been examined, there is no proof of any great break in time. A considerable difference in the flora of each group of rocks may be traced, but this difference would appear to be due rather to varying conditions of the surface, than to any great change indicative of a considerable lapse of time, inasmuch as several plants pass from one group to the other.

Since the above was sent to press, Mr. Blanford has been rewarded by the most valuable discovery of reptilian remains in the uppermost group of this field. These have only been found within the last few days, and have not as yet been examined. But the fact of the occurrence of animal remains of any kind is in the highest degree interesting, as no trace of any thing but vegetable relics had previously been seen in these rocks. And as I have already remarked, it is well known how untrustworthy their evidence is, in determining the relative age of the rocks in which they occur.

(*a*) Memoir of Geol. Surv. of India Vol. I. p. 46.

(*b*) Ditto ditto Vol. II. p. 176 &c.

To elucidate the history of these beds a little more clearly, it will be necessary to revert to earlier researches, and at the same time to anticipate to some extent the publication of matter of great interest and importance in Indian Geology.

In the year 1854 a brief summary of the results of an examination of the Rajmahal hills, which had been made during the cold seasons of 1852-53, was published. (*a*) In that abstract, I insisted upon the marked separation which existed physically between the "coal-bearing" rocks which occurred in all cases beneath the great overflowing sheets of trappean matter, and those inter-trappean beds which had been tranquilly deposited upon, and again subsequently covered up by, the successive outbursts of those ancient lavas. While thus necessarily unconformable, it was shewn also that this very marked physical break in continuity was accompanied by a continuance of the same general conditions and kind of deposit. Thus, while thick and useful beds of coal might not be found in the upper system, as they were in the lower, still the conditions for its formation existed, as was evident from the frequent occurrence of thin layers or beds of bituminous shale, and in several cases of carbonized stems, and fragments of plants.

The entire series, in the then state of our knowledge of the contained plants, was considered to represent one great system or formation, marking only one continuous but great interval of time; but at the same time capable of most ready and most marked separation into two groups, the upper and lower. We shall allude again to the fossil evidence.

To this upper series, we had for years appropriated the distinctive name of the *Rajmahal* series.

Such being our information up to the time of Mr. Medlicott's labors in the Nerbudda, he found there a series of rocks which in very many respects agreed with these *Rajmahal* beds; namely, in being unconformably superimposed on the true coal-bearing or Damūda rocks; while at

(*a*) Jour. Asiat. Soc. Bengal Vol. XXIII p. 263.

the same time they appeared to be linked to them as part of a sequence by the continuation of the same conditions of deposit, and by the *apparent* presence of some few identical plants in both. Finding, I say, these facts, he was disposed to consider them identical with, and to give to them the same name as, the "*Rajmahal*" beds. For this identification, however, there did not appear to be perfectly satisfactory, or sufficient ground. And as the plants preserved in these beds had not, up to that time, been fully examined, it was not possible to come to any definite conclusion on the matter. There seemed at first sight, a general resemblance, combined with some marked differences between the flora of the two groups. But until a careful examination of all the collections had been made, it was thought more desirable to continue the same general principle of nomenclature, and to speak of these Nerbudda beds, as belonging to the same great formation, but as being *Upper Damuda.*

MAHADEVA ROCKS.—We have above alluded to the fact (known so long since as 1852-53,) that there existed in Bengal a great thickness of rocks newer than, and separated by a distinct unconformity from the true Damūda (or as we were in the habit of calling them previously to 1856, the "coal bearing") series, but still, as we then believed, connected with that series. This had quite prepared us for the discovery of other groups in a similar position elsewhere. And when, in 1856, I had an opportunity of visiting the Nerbudda district, and passed the noble scarps of the Puchmurri hills, where massive sandstones many hundred feet in thickness stand out boldly in almost precipitous cliffs, their nearly horizontal beds resting on the much disturbed Damūda rocks beneath, the eye at once recognized the distinctness, and the two groups were separated. A little further examination, however, proved most clearly that we had in these upper beds of Central India, no representatives of the beds known to occur unconformably over and in succession to the Damūda beds in Bengal. (*a*) In every respect—in mineral

(*a*) Mr. Medlicott's Upper Damūda group had not then been worked out.

character, force of deposit, &c., in contained organic remains, there was a marked and obvious distinction, and it was at once seen that we had a new group of rocks altogether. Following up these enquiries, we found what seemed to be the upper limit of this series: and from the hills, in whose bold scarps and glorious precipices these rocks were best seen, the name *Mahadeva* was given to the group in May 1856 by myself.

Working during the same season, in Talcheer, Mr. H. F. Blanford had traced out, "an absolute though slight unconformity between the grits of the upper sandstone and the underlying shales and sandstones" (the Damūda, as since called): I gladly take this opportunity to state that this discovery of the unconformity of the two was made by Mr. H. F. Blanford a few days prior to my visit to the Puchmurri or Mahadeva hills, although the announcement of it, communicated by post, did not reach me till some days after.

The existence of a considerable thickness of sandstones resting unconformably on the Damuda series having been thus established in Cuttack, (quite independently of my own researches in Central India), the same name, which I gave to those in Central India, was applied by the Messrs. Blandford to these grits and sandstones. The rocks beneath these sandstones were from the identity of their imbedded fossils known to be the same in both places, and to belong to the great system called by me the Damūda. And it was presumed that these upper, and unconformable grits and sandstones were also identical with the typical rocks (*Mahadeva*) in Central India. There are, I believe, strong reasons for doubting this identity, and for thinking that the Cuttack "Mahadeva" beds represent rather the upper grits and conglomerates of the Damuda field, but until there be an opportunity of making an actual comparison, the name must stand.

This *Mahadeva* group, as known at the time of the earliest published notice of it, Mr. Medlicott has subsequently sub-divided, adding a very interesting and important group to which he has given the name

Lameta from the Lameta Ghat, near Jubbulpur, where the rocks are well seen.

With regard to the classification of the upper tertiary and recent deposits, I shall not at present add any thing. The area described is too limited to admit of any general discussion of the question.

In the foregoing statements I have endeavoured to give as succinctly as was consistent with clearness, the several steps by which my colleagues and myself, while engaged in the Geological Survey of India, have, as it were, groped our way amidst the uncertainty and darkness which surrounded the formations with which we had to deal, and how, by successive steps, we have been able to reduce these to some order and system.

Having thus arrived at a knowledge of the general succession of the rock-masses, it remains now to give an equally brief summary of the fossil evidence which has been accumulated up to this time, and to shew how far it may suffice as a foundation on which to build any satisfactory conclusions regarding the geological age of the various groups or series of rock-masses enumerated above.

In this review of the whole series, we may, at present, omit altogether the Sub-Kymore group and the Vindhyan system, since they have hitherto proved unfossiliferous. On the other hand, as having little in common with the rocks below them and as being, as I think, widely separated from them, we may also reserve the consideration of the Mahadeva group.

We have, therefore, the Talcheer, the Damūda, upper Damuda and Rajmahal, groups remaining, and shall briefly notice their relations.

From all these, in varying number and abundance, fossil remains of plants have been obtained. From none of them, (with the exception of the important discovery within the last few days by Mr. Wm. T.

Blanford in the upper beds of the Ranigunj district,) have any animal remains whatever been procured, save one solitary wing-cover of a beetle! We speak, of course, only of those districts which the survey has visited and examined. In an unknown country like this, where we have in fact no horizon as yet fairly established, from which we can start, this limitation must always render our conclusions more doubtful, and unsatisfactory. But we shall endeavour to state them as clearly, as the unavoidable absence of the necessary illustrations and detail will permit.

Up to the date of my brief notice of the geological structure of the Rajmahal hills, (1854,) and for some time after, it had not been possible, from the want of the necessary works for reference, as well as from the pressure of other business, to undertake a full and careful examination of the rich collections of fossil plants which we had at various times brought together from the Rajmahal hills, and other localities.* The discovery in 1856, by Mr. Jos. G. Medlicott in the Nerbudda district, in his "*Upper Damuda*" group, of other fossils which appeared to resemble, or to be identical with, those found in the Rajmahal district, compelled however the taking up of this examination. I am indebted to my friend, Professor Morris of London, for having very carefully gone over, examined and described the majority of those from the Rajmahal hills. And the remainder have been carefully examined and compared. Of the group there found, I am therefore able to speak with considerable certainty, and in some detail. The *Upper Damuda* plants of the Nerbudda have also been gone over so far as the collections made by Mr. Medlicott under some difficulties, enable this to be done. But we have not, as yet, equally extended or equally valuable data for this group as for the upper beds of the Rajmahal hills.

The fossil flora of the Damūda group has been to a certain extent investigated, but for this group our materials are daily increasing, and we are therefore not able to do more than speak in a general way.

* Indeed, until the formation of the Geological Museum in 1857, there was no place in which this could have been done.

From the *Talcheer* rocks wherever seen, only a very few specimens have been obtained, and those often not in a good state of preservation.

If then we take the uppermost system, being that whose flora we know best, as a standard, let us see what evidence, or even what clue towards evidence, we can get from it as to the geological epoch of the rocks in which these fossils occur.

In these RAJMAHAL beds we have the following group of plants:—

Of *Algæ*, *Lichens* or *Fungi*, none.

Equisetum, ...	2	4
Cyclopteris, ...	1	
Dictyopteris, ...	2	
Pecopteris, ...	5	
Sphenopteris, ...	3	
Tæniopteris, ...	3	
		14
Cardiocarpon, ...	1	
Lycopodites, ...	3	
Walchia, ...	1	
		5
Cycadites, ...	2	
Pterophyllum, ...	9	
Palæozamia, ...	8	
Stangerites, ...	2	
		21
Voltzia, ...	1	
Brachyphyllum, ...	1	
		2
		46

Dadoxylon (wood,)

Palæoxylon,

Taxoxylon,

Cycadeous wood,

True Dicotyledonous angiosperm wood, 3 or 4 varieties.

In all (exclusive of the woods, which represent many varieties but most of which probably belong to the same plant of which other parts are preserved in other specimens), some 46 species or varieties.

At the first broad view, the presence of dicotyledonous angiosperms would at once indicate that this flora represented a period more recent than the true coal-measures of Europe, if the opinion of M. Brongniart, unquestionably one of the highest authorities on the subject, be correct.(*a*) But all such conclusions based upon merely negative evidence are I believe utterly untrustworthy, and can afford no truly sufficient ground for reasoning.

The general character of this flora is at once marked by the number of Cycadaceæ, which constitute nearly one half numerically of the entire group (21 out of 46). But these form the prevailing characteristic of the flora to a much greater extent, even than these numerical proportions represent, from the size, abundance and luxuriance of growth of the individuals of those species. Slabs of several square yards could frequently be obtained, whose surfaces would shew nothing whatever but the matted leaves of these plants, often most beautifully preserved. On the other hand, while there appear to be representatives of no less than 14 well marked species of Ferns, this interesting group of plants is by no means so abundantly represented, and examples of these varieties are comparatively rare.

Viewed in its geological relations, this flora at once proclaims itself as *Mesozoic*, and at first sight, it would even appear to be *Upper Mesozoic*. Such is, undoubtedly, its general aspect.

Examining it more in detail, we find unfortunately few out of the total number of species noticed, which can be identified with others known to occur elsewhere. There are, however, some, and these are of great importance. Of the cycadeæ, two are (as was originally indicated by myself in 1854) identical with similar plants from Cutch described by

(*a*) Annales des Sciences Naturelles, Ser. 3. Vol. V, p. 61.

Professor Morris in 1836 * under the generic name of *Ptilophyllum*. Of the ferns, one *Tæniopteris* (a genus only known in *Mesozoic* and *Cænozoic* rocks) seems undistinguishable from the *T.* (*Otopteris*) *Ovalis* (L. and H.) from the oolitic shale of Gristhorpe Bay: while the remainder find their nearest analogues, among described species, in those which are of the same general age. To this general result there is one marked exception in the occurrence of two varieties of the peculiar genus *Dictyopteris* (*Linopteris*) no specimens of which have as yet been found in rocks of a more modern epoch than the true coal-measures of Europe.

Of the *Pecopteridæ* one very abundant form is *Gleichenites*, a palæozoic form. Of *Cyclopteris* (a genus in which the majority of the species are palæozoic, although its representatives extend upwards into the newer Mesozoic era) we have but one species. *Sphenopteris* is equally a genus as strongly, if not more strongly, represented among the palæozoic rocks, than among the newer groups.

The remains of ferns, therefore, are such that the group might be supposed either Palæozoic or Mesozoic.

We may pass over the *Lycopodiaceæ* as they are not sufficiently characteristic to prove any thing definite.

Of the *Cycadeæ* the genus *Cycadites* is hitherto only known from formations truly Mesozoic, with the exception of one species (doubtful) from the coal-measures. *Pterophyllum*, and *Palæozamia* again are truly Mesozoic genera, while the genus *Stangerites* was established by Borneman for plants found in the Liassic *Lettenkohlen Grappe* of Thuringia.

Voltzia, again, is hitherto only known as a Triassic genus, and *Brachyphyllum* as Jurassic.

It would seem therefore, from an examination of the general characters of this flora, that it might, without in the least degree straining the evidence, be taken as representative of *any* period within the great

* Transactions of Geol. Soc. London 2nd Ser. Vol. V, p. 327.

Mesozoic division of stratified rocks. At the same time the prevalence of the cycadeous type and more especially of the *Pterophylla* seems to indicate an upper Mesozoic age. If a closer examination be made, it will be found that, so far as the plants from special groups of European rocks have been published, this flora of the Rajmahal group offers numerous points of resemblance and analogy with the flora of the Wealden group of North Europe*—while at the same time there are very strong analogies and resemblances to several of the plants known to be peculiar to the Permian group of Saxony and Bavaria.†

There has been much stress laid, and most justly laid, by Mr. Hislop on the marked analogies which some of his Nagpur fossils offered with those which have been described from the Richmond coal field in Virginia, which had been referred to the age of the lower oolite of Europe. But a more recent and more detailed examination of the fossil plants from that district by Dr. Heer, Zurich, has shewn that they agree generally, and many of them specifically with those of the Upper division of the European trias, the Keuper. This evidence would seem to be confirmed by the occurrence of fish of the genus *Æchmodus*, (Egerton) to which genus also belong those fish remains, with unicuspid teeth, which had been originally described as belonging to the genus *Dapedius*. The evidence derived from a comparison of the Virginian coal strata would therefore go to prove that these beds belonged to the triassic era.

Emmons‡ has recently described in some detail the fossils found in the well known Chatham coal field in North Carolina, which is, I think, unquestionably of the same age as the Richmond coal field in Virginia. And among his fossil plants are many almost undistinguishable from some that occur in our Rajmahal beds, while the general facies is remarkably similar. This again affords cumulative evidence that these Rajmahal

* Dunker, Monographie der Norddeutschen Wealdenbildung, 1846.

† Geinitz und Gubtier des Permischen systemes in Sachsen 1848.

‡ Emmons. American Geology Part VI. 1857.

beds represent some portion of the older parts of the great Mesozoic period.(a)

Such is the evidence from fossils. Have we any from physical character and position? We have already alluded to the identity of the fossil *Zamiæ* found in these Rajmahal beds, with those obtained from Cutch, by Capt. Grant, and described by Mr. Morris, in 1837: an identity confirmed by Mr. Morris himself after careful examination of the specimens. There are only two other genera noticed, a *fucoides*—erroneously so described, I believe from an imperfectly preserved and injured specimen,—and a *tycopodites* which I believe is identical with some from the "Rajmahal" beds. We must, therefore, admit that this "Rajmahal" group is identical in general geological age, with the group of rocks in Cutch, described by Captain Grant under the name of, "Sandstone and clay with beds of Coal." Now these beds with coal, in Cutch, are by Captain Grant stated to be quite distinct from, and to be unconformably covered by the series called by him, "Laminated series or Upper Secondary Formation," in which upper series occur all those well preserved fossil shells described in the same paper by Sowerby, and the oolitic age of which cannot be doubted. The group appears, in fact, to represent a lower oolitic era, the whole series of molluscous remains (in connection with other fossils also described by Sowerby) indicating an epoch extending from the Cornbrash to the great oolite of England.

The physical relations of these beds with those containing the fossil plants were not very distinctly made out by Captain Grant; but if his description can be trusted, it would appear certain that the beds containing these undoubtedly oolitic forms of marine mollusca, rest upon, *unconformably*, and are, therefore, more recent than, the beds with fossil plants and coal. In one case, Captain Grant states, that they "certainly

(a) We would add that among a small collection of Keuper plants from Veitlahm near Culmback Bavaria, lately procured for our Museum in Calcutta, are several almost undistinguishable from some of our *Rajmahal* plants.

occupied a hollow in the coal sandstone,"(*a*) and he thinks that this is the general fact also.

Such a marked break in continuity of deposit accompanied by a considerable amount of denudation of the lower group, would seem to indicate a considerable lapse of time between the two deposits. But, without in the least giving too much weight to this fact, it unquestionably follows, that the beds of sandstone with coal in Cutch are decidedly not more recent than the epoch of the lower oolites of England, and are possibly much older. And as a consequence of this, that the "Rajmahal" beds, which contain identical fossils are equally not more recent than the same epoch—the lower oolite.

But we have obtained some further evidence also, and from a different locality. Beneath the whole of the cretaceous rocks so well developed in the district of Trichinopoly to the south of Madras, and from which such a beautiful series of fossils were described by Edward Forbes,(*b*) beneath the lowest of these beds, occur a series of soft whitish, and greenish-white sandstones and pebbly beds, generally soapy to the feel, and regularly bedded. In these, remains of Zamiæ had been first found by Mr. Chas. Æ. Oldham in 1858. These beds are separated by a marked and defined unconformity evidencing a very considerable lapse of time from the marine cretaceous beds, and are thus separated from the lowest division of these cretaceous rocks, which division, so far as the fossil evidence has been examined, are certainly not more recent than the *étage Aptien* of D'Orbigny, or the upper portion of the lower green sand of English Geologists.

I had an opportunity of examining these sandstones, (the age of which, as undoubtedly precretaceous is thus fixed,) during last year, and in them I found remains of two Palæozamiæ, (*P. cutchensis* and *P. acutifolium*), identical with those occurring in the "Rajmahal" beds and identical also with those found in Cutch. With these cycadeous remains, I found

(*a*) Trans. Geol. Soc. London, Vol. V, 2nd Series, p. 297.
(*b*) Trans. Geol. Soc. London, 2nd Series, Vol. VII, p. 97.

also a fern (*Pecopteris* (*Gleichenites*) *linearis*, M. S.) identical with one plentifully associated with the Palæozamiæ in the "Rajmahal" beds. A *Stangerites* (*Tæniopteris*) was also found, and many stems, which however, were not distinguishable. All these fossil plants found in the beds in the Trichinopoly district, are identical with others from the "Rajmahal" series, and they must, I think, be admitted as proving these beds to be of the same geological epoch as our "Rajmahal" group. And that this age, whatever it were, was undoubtedly pre-cretaceous.

I have thus, I think, established with tolerable certainty that these "Rajmahal" beds must represent some portion of the older Mesozoic groups of European geologists. I purposely avoid at present arriving at any more definite or closer result.

We have still to see the relations of the other groups, or systems of rocks which we have established, the *Upper Damuda*, *Damuda* and *Talcheer*, with these "*Rajmahal*" beds.

And first as to the UPPER DAMUDA of Mr. Medlicott's classification.

Our collections of fossil plants from this group contain many forms which are not represented in the "Rajmahal" flora. These chiefly consist of conifera (*Taxodites*, *Cupressites*, *Widdringtonites ?*) which occur in considerable number, of large grass like stems, and of Lycopodiaceæ. One *Walchia* seems to be identical with a "Rajmahal" form—of cycadeæ there are numerous detached leaves, and a large number of what seem to me to be the detached scales or bracts of the cones of cycadeous plants, occurring separately. These are, I believe, the *paper-kite* fossils of Mr. Hislop, and probably of the same kind as the "winged seed" figured by Phillips* from the lower sandstone and coal of Yorkshire. There are similar remains in the "Rajmahal" beds.

One *Palæozamia* also is identical in both groups. These identical fossils although few, seem sufficient to place the UPPER DAMUDA beds, of Mr. Medlicott's report, on about the same geological horizon as the

* Geology of Yorkshire, Vol. I, Pl. 10, Fig. 5.

Rajmahal beds. The "Upper Damuda" group appears in fact to represent more fully in the Nerbudda district than it is seen in the Rajmahal hills the lower portion of our RAJMAHAL SERIES.

We now turn to the most important and valuable series of rocks, to which we have given the name of the DAMUDA SERIES.

Incidentally I have mentioned above (in a note page 176) that there does not exist in the collections in our Museum in Calcutta a single fossil common to both the "UPPER DAMUDA," and the "DAMUDA" series of the Nerbudda district. It will be seen on a reference to my notes on the Rajmahal hills, published in 1854, (*a*) that, at that time, while fully recognizing the marked difference in the contained fossils between the upper and lower groups into which we divided the whole series, we still thought that at least two genera—*Vertebraria* and *Glossopteris* were represented in each group, by common species. More careful and detailed examination of greatly extended collections have, however, satisfied us that in this we were in error. The fossils mistaken for *Vertebraria* were imperfectly preserved fern stems; nor have we been able to trace, among several thousand specimens, a single representative of the genus *Glossopteris* from any part of these upper or "RAJMAHAL" beds.

So far, therefore, as we know, up to this date (1860) not only are the "Rajmahal" beds separated by a marked break in physical continuity, from the "Damūda" beds below, but *also by a marked and total change in the vegetation*, remains of which are so well and so numerously preserved.

All these facts seem to point to a great lapse of time between the period of the deposition of the Damūda beds, and that of the formation of the Rajmahal group.

If then it be admitted that we have above satisfactorily established our argument that the Rajmahal series must be taken as representative of some portion of the lower Mesozoic system of Europe, (probably

(*a*) Jour. Asiat. Soc. of Bengal 1854, p. 272.

even so old as the Triassic); it will follow that we must seek for the representatives of our DAMUDA series, in some decidedly older group among the established series of European geology.

As we have already said, our collections from the "Damūda" beds are still increasing rapidly, and we cannot speak of the whole flora with the same confidence, as for the Rajmahal beds. Still our collections *are* sufficient to enable some conclusions to be arrived at.

The "Damuda" flora, contains so far as we know, the following:

Of Cellular plants, two or three genera.

Sphenophyllum,...	3
Vertebraria, ...	2
Phyllotheca, ...	2
Cyclopteris,(?)	1
Pecopteris,...	4
Glossopteris, ...	5 (?)
Calamites,...	1
Schizoneura,...	2
Zamia(?)	1 (?)

Besides wood &c.

The remarkable contrast which this flora presents to that from the "RAJMAHAL" series will at once be seen on comparing the list here given with that at page 318. Instead of *Cycadeaceæ* composing nearly one half of the entire flora (as preserved) we have only one doubtful specimen (*a*) (not species). The presence of *Sphenophyllum* (*Trizygia* Royle) locally abundant, the constant occurrence, all through the series, of *Vertebraria* in great variety both in size and number; the abundance of

(*a*) This specimen was figured, along with others, in a series of plates which were prepared many years since, with a view to their publication in the Asiatic Researches, accompanied by a description of the plants by Dr. H. Falconer. This description never was completed, and the plates were consequently never published. Many of the figures then engraved were repeated by Dr. McClelland in the very inferior representations given in his Report of the Survey of parts of Bengal in 1848-49. Among others, this figure of a *Zamia*, to which Dr. McClelland gave the name of *Zamia Burdwanensis*. All the specimens

Glossopteris so markedly absent from the upper group, and so universally present in this series, are all prominent and easily recognized distinctions. To these we may add the presence, locally very abundant, of beautiful specimens of the curious genus Schizoneura.

The total and marked difference in the two floræ being thus established, we have yet to see to what epoch in the established system of Geological groups, these rocks probably belong. To this end, we shall compare in a little more detail some of the fossils.

The genus *Schizoneura* of which we have abundant representatives belonging to certainly two, perhaps more, species, has hitherto only been found in the Triassic rocks of Europe. It was established from some fossils from the Vosges sandstone.(*a*) The *Zeugophyllites* given by Brongniart, as occurring in the Indian coal group (Prod. 118-121) and specimens of which were figured by Strzelechi from Australia (*b*), appear to be nothing more than a group of the leaflets, or a portion of the leaf of *Schizoneura*.(*c*)

Vertebraria has never hitherto been found, excepting in India and in Australia. In both these countries it is remarkably abundant. The species or varieties in both are also identical. I cannot agree with some recent authors in referring this curious fossil plant to the genus *Sphenophyllum*. After a careful examination of hundreds of specimens I can

figured in this series of plates are now in the collection of the Government Geological Museum, Calcutta, *with the exception of this one*: and I cannot help thinking that a fragment of a *Schizoneura* has, in this case, been mistaken for a *Zamia*. Certain it is, that we have never been fortunate enough to meet with a single specimen of any Cycadeous plants in these beds. I am disposed, therefore, to reject the evidence of this figure, unsupported by any specimen.

(*a*) Schimper et Mougeot. Plantes fossiles du gres bigarré de la chaine des Vosges. Leipzig 1844,

(*b*) Strzelechi, Physical description of New South Wales, &c. Lond. 1845.

(*c*) The plant figured in the Trans. Geol. Soc. London second series Vol. VII, Pl. XXVIII, fig. 1, appears to me to be a true Schizoneura, preserved on a plane at right angles to the axis of the stem, or nearly so, and shewing two of the amplexicaul leaves, or groups of leaves, pressed together in the rock. It is from the Dicynodon strata of South Africa.

see nothing to justify the idea that we have the leaves of a plant in any of its forms; and I am disposed to think that Vertebraria will prove to be a root, with smaller rootlets attached. Certain it is, that these puzzling fossils are found under circumstances which indicate that their vegetable matter contributed very largely to the formation of the coal of this country; and to a great extent they play the same part in the Indian Coal-field that *Stigmaria* does in English fields.(*a*)

Of *Phyllotheca* we have at least one, probably several. Of *Pecopteris*, our specimens shew I think, that *P. Lindleyana* of Royle is identical with *P. Australis* of Morris. Of *Sphenopteris*, one species is certainly common to Australia; one approaches very nearly to *S. bifida* of the Scotch Coal measures.

There remain then the remarkably numerous and largely varied forms of *Glossopteris*. This in fact from its great abundance and from the great size of many of the leaves, is *the* most characteristic fossil of the group. And it may be necessary to say a few words regarding this genus of ferns.

In the Indian Coal-fields we have all the varieties known from Australia, and all the typical varieties described by Brongniart, together with several others not hitherto figured. I cannot trace the grounds on which it has been so frequently and positively repeated that Glossopteris is a "truly characteristic oolitic genus." This assertion has been reiterated so constantly, as to have formed the basis of much reasoning on the age of the rocks in which Glossopteris leaves have been found. It is one of the strongest arguments given by Mr. McCoy in his summary of the evidence from the Australian plants.(*b*) It is equally one of the strong points urged by Mr. Hislop in his discussion of the age of the Indian coal-strata. It is by others called a "distinctive oolitic genus*" "a genus of oolitic ferns." &c.

(*a*) See Logan's valuable paper. On the character of the beds of clay below the Coal seams of South Wales, &c. Transac. Geol. Sur. London, Vol., VI. 2nd Series, p. 491.

(*b*) Annals of Natural History, London, 1847, p 310. Vol. XX, 1st series.

* Miller Testimony of Rocks p. 483, &c.

The total number of fossil species of this genus which had been described up to the date (1850) of Unger's valuable *Genera et species plantarum fossilium*, was eight considering the two distinct forms described by Brongniart and by Lindley and Hutton under the same name as two species. Of these eight, *G. dancœoides* (Royle) has long been known to be not a *Glossopteris*. *G. dubia* of Brongniart, is now considered a *Lepidophyllum*, but is in any case a Carboniferous plant: *G. Willsoniana* (Sternberg) is a *Tœniopteris*; while the *G. Phillipsii* of Brongniart, from Scarborough, is also a true *Tœniopteris*, and *G. Phillipsii* of Lindley and Hutton is considered, on the high authority of Unger, to be identical with the *Pecopteris longifolia, and paucifolia* of Phillips, and is transferred to the genus *Acrostichites* of Goppert or *Sagenopteris*. Another species, not given in Unger, is *G. acaulis* of McClelland (*a*) which is undoubtedly not a glossopteris. There remain therefore only the *Glossopteris angustifolia, G. Browniana*, and *G. linearis* representing the genus. All of these are peculiarly Indian or Australian species, and are characteristic of our "Damuda" rocks, whatever the geological age of these may be. But there is not in this important and numerously represented genus a single species known from any group of rocks in Europe, the geological position of which is established. (*b*) This is of importance as connected with the age of these rocks.

If we consider, with Unger and others that the *Glossopteris dancœoides* of Royle is a true *Pecopteris*, we shall then have not a single representative of that genus *Tœniopteris* in these "Damuda" rocks. The *Poacites* of McClelland (2 species) are based upon specimens of stems of other plants.

From this enumeration it follows, that we have as yet but few data on which to base any comparison with European rocks. The occurrence of

(*a*) Report of Survey of part of India 1848-49, Calcutta 1850.

(*b*) Bronn. in his lists, *Lethæa Geognostica*, gives only the three species noted above, and gives all as *Carboniferous*. 1856.

Schizoneura abundantly represented, if it prove any thing, would seem to indicate a Triassic era. But there is little else on which to found any conclusion, if we examine these beds alone. We are, therefore, driven to see what clue to the age of these rocks we can find from a comparison with other countries.

That which offers us the best means of drawing such a comparison is Australia. There we have beds containing many plants almost all of which are identical specifically with the plants found in these "Damuda" rocks in India; and there can be little question, that the two series, the plant bearing sandstones and shales of Australia, and these "Damuda" rocks of India, are at least nearly cotemporaneous, if not truly synchronous.

It has long been known to Geologists, from the zealous labors of Strzelecki, Clarke, Darwin, Jukes, and others, that stretching at irregular intervals along the eastern coast of Australia, and now occurring in detached masses, probably once continuous, there occurred a series of stratified deposits which contained abundantly, in different parts of the range, remains of fossil animals and plants.

The general section of these is given in clearest detail by Jukes, and we shall quote his words.

"*In the descending order.*

1. Black and brown shales (named, I think, by Mr. Clarke, Wyanamatta shales) 300 feet and upwards.
2. The Sydney sandstone, (or Hawksbury Sandstone), thick sandstones, with a few thin beds of shale in its upper and lower parts; about 700 or 800 feet.
3. Alternations of sandstone and shale; about 400 feet.
4. Alternations of sandstone and shale, with much fossil wood (often drifted) and some beds of Coal; 200 or 300 feet.
5. Wollongong sandstones, with calcareous concretions, containing many fossil shells and corals, and some fossil wood; 300 or 400 feet."

From these rocks Strzelecki brought to England a good collection of fossils, which were examined and described by Lonsdale, Morris, &c.

subsequently a larger collection was transmitted by the Revd. W. B. Clarke, and examined and described by Professor McCoy. By all these competent authorities the very striking agreement between the fossil mollusca and corals from these Australian beds and those from the lower carboniferous rocks of Europe, (this agreement being not only in the general aspect or *facies* of the group, but also in specific identity of many of the fossils), was pointed out. While on the other hand, in reviewing the group of fossil plants from these beds, Mr. Morris distinctly called attention to the absence of those forms which in Europe and America were found abundant in, and were characteristic of, the carboniferous rocks. He also noticed the peculiar resemblance, in some of the forms, to species known only from the oolitic rocks of Europe, remarking at the same time, the close analogy of one form with a Permian fern, from Russia. Mr. McCoy also, after noticing similar facts, sums up the evidence from these plants, thus.—Of the 10 genera into which he divided the entire collection submitted to him, two were known only in these Australian beds, and in our Indian fields (*Vertebraria and Zeugophyllites*); one, (*Gleichenites*) "found only in the palæozoic coal" remarking however, (and this is worthy of notice) "the plant agrees much better with the species of the keuper genus *Heptacarpus*, than with those of the carboniferous *Gleichenites*."—"All the other genera, (with the exception of *Phyllotheca*, which is confined to the locality) are well known in the oolitic coal deposits of Yorkshire," &c. * * * "Several of those genera are common both to the carboniferous and oolitic periods, but the most abundant and characteristic plants of the Australian beds belong to a genus (*Glossopteris*) never found in the old coal-fields, but several species of which are, on the other hand, well-known in coal-beds of the oolitic age in various parts of the world." Further remarking, as had Mr. Morris previously, on the negative evidence of the total absence of Sigillaria, Stigmaria, Lepidodendron &c., forms so abundant in European coal-measures, he concludes from all the evidence—"I do not think

it improbable that a wide geological interval occurred between the consolidation of the fossiliferous beds which underlie the coal, and the deposition of the coal measures themselves; that there is no real connexion between them—but that they belong to widely different geological systems, the former referable to the base of the carboniferous system, the latter to the oolitic, and neither shewing the slightest tendency to a confusion of type."

This it must be remembered was merely a speculation based upon a cabinet examination of the fossils. I presume similar reasonings have influenced more recent writers who have unhesitatingly referred these plants (as it appears to me on very unsound evidence) to the oolitic epoch. (*a*)

Let us then consider in a little more detail what this evidence is. And first as to the physical evidence. Jukes, writing in 1850, (three years after the publication of McCoy's valuable papers) and doubtless having the view therein expressed in his mind, says thus.—"Some persons have been struck with the oolitic aspect of the fossil plants collected in New South Wales, (as also of those of India,) and have been led to imagine, in consequence, that they did not belong to the same formation as that in which the Productæ, Spiriferæ, &c. above named, are found. All the physical characters and relations of the rocks, however, both in New South Wales, and Tasmania, led me to look upon the whole series as one great continuous formation, and Mr. Clarke has since distinctly informed me that he has obtained the same Spiriferæ, Productæ, &c. from beds above those which contain the fossil plants, as are found in the beds below."

"The perfect conformability and apparent passage from one group into the other would of itself render highly improbable any such difference of age between the higher and lower beds as exists between any

(*a*) De Zigno. Flora Fossilis Formationis Oolithicæ. Unfortunately the introduction to this most valuable and beautifully illustrated work has not yet appeared, so that we do not know the author's reasons for considering these Australian and Indian plants oolitic.

palæozoic, and any oolitic formation." Such was also the view of all those who had the opportunity of studying these rocks *in situ*. While therefore, there is no question that the coal-beds of the Australian fields, are newer than the group of rocks containing fossils identical with species known only in other countries as of the lowermost portion of the great Carboniferous system, or of the Devonian, there seems to be equally little question, that there is no physical evidence of there having elapsed between the formation of the two groups (the Sydney sandstone and shales, and the Wollongong sandstone) any such interval as would warrant our referring the upper series to a period so widely, so immensely separated from the lower carboniferous period, as that of the lower oolite must have been. On the contrary, all the probabilities of the case would suggest that this upper group represented the upper portion of the same great palæozoic epoch, to the lower or more ancient portion of which same epoch, the underlying beds containing marine remains in abundance unquestionably belong.

And if this be admitted, it will follow that our "Damuda" series equally represent an upper Palæozoic era.

Another district which will hereafter, when its fossil plants shall have been worked out, afford many and valuable points of comparison is that richly fossiliferous series of rocks in South Africa, described by Mr. Bain and others.

A cursory inspection of a few of the fossil plants from that district satisfied me of the marked resemblance which many of them offered to our Indian plants.

The *probability* therefore would seem to be that our "Damuda" system belongs to some portion of the upper *Palæozoic* division of European geological sequence, or to the lowermost portion of the Mesozoic division. In fact, we may possibly hereafter find that it will represent that great interval indicated by the marked separation and great break between the two series in other countries.

We have purposely avoided complicating the argument derived from our knowledge of these rocks in Bengal and in part of Central India, by any reference to other districts in India, which we have not ourselves been able to visit, however much such a process might be calculated to throw light on the questions we have discussed. One of these districts is the Nagpur country, so admirably described by Messrs. Hislop and Hunter. It is clear from the papers of these observers themselves that much yet remains to be done in making out the physical relations of the different groups before we can admit the reasonings they have founded on a consideration of fossils obtained at great distances—and from beds, which are only *supposed* to belong to the same sub-division of their classification. We may very briefly remark, that the upper group (A) of Mr. Hislop's series is very probably synonymous with our *Mahadeva* group. In these beds in Nagpur, no fossil plants with the exception of a few stems of trees *in situ* have been found, excepting in rolled blocks of previously existing rocks, imbedded in these upper sandstones. This fact in itself proves that there had elapsed a long interval of time and that great changes in the physical conditions of the district had occurred, subsequently to the deposition of his second group (B) and that the two are therefore, in Nagpur as elsewhere, quite unconformable. In this group (B) I think, it will be found that beds representing in part our "Rajmahal" series, and in part our "Damuda" series have been brought together. I judge so from the curious admixture of fossils which in the districts we have been more particularly speaking of are found so widely distinct. The red shaly beds, and argillaceous strata of Mr. Hislop's group C. *may* be representative of our *Talcheer* group. From Mr. Hislop's own account they would appear to be unconformable to the group B. The only fossils found in these are stated to be a reptilian (?) foot mark, traces of worm-like animals, and a supposed Phyllotheca.

I do not refer to his group D, including crystalline limestone, &c.

which are, I think, obviously of a totally different age.(*a*) The Umret beds referred to by Mr. Hislop in a subsequent paper,(*b*) are "Damuda." It is I think very doubtful if the Kota beds are of the same age. The evidence derived from their abundant fish remains; that from the occurrence, at Mangali, of the remains of Labyrinthodont reptiles, (*Brachyops laticeps*) and again of the abundant representatives of the genus *Ceratodus*, at Maledi, convinces us that when the true physical relations, and succession of these different groups have been made out, all these links, now detached, and separate, will form one continuous chain, each finding its own proper place in the system. And I think, great as the delay may be, it is safer and wiser not to hazard any erroneous conclusions by hasty speculation.

Talcheer Beds.—From this lower group we have very few fossils. These consist of a *Phyllotheca* (?) a large *Cyclopteris* like leaf and some annelide markings. Data quite insufficient on which to base any conclusion as to the age of the group. They seem, however, to indicate that it is only a somewhat older sub-division of the great "Damuda" series; and this supposition is also borne out by the apparent passage of one into the other in the Nerbudda, (and elsewhere).

We shall reserve the discussion of the age of the Mahadeva series of the "Intertrappean lacustrine" beds, and of the Miocene (? pleiocene) ossiferous beds of the Nerbudda valley—for another opportunity.

(*a*) Quar. Jour. Geol. Soc. London, Vol. XI, p. 345. (*b*) Ibid. p. 555.

List of papers relating to the district of the Nerbudda &c., published previously to the date of this Volume.

For the convenience of those who may desire to investigate more closely the history of our knowledge of Central Indian Geology, by referring to the original papers bearing on the subject, I will give here as complete a list of all the essays and notices relating to the district reported on above, and to the immediately adjoining country, as I have been able to form. These are arranged in the order of the date of publication. (T. Oldham.)

N. B. The letters J. A. S. B. refer to the Journal Asiatic Society Bengal.

1823.	Dangerfield, Capt. F.	In Malcolm's "Memoirs of Central India including Malwa." Vol. II. Appen. No. II. Gives Geological map of Malwa, &c.
1829.	Franklin, Capt. J	On Geology of Bundelcund, Boghelcund, Saugur and Jubbulpur, Asiatic Researches, Volume XVIII, p. 23.
„	Coulthard, Capt.	On trap formation of "Sagur district," Asiatic Resear. Vol. XVIII, p. 47.
	Franklin, Capt. J.	On the diamond mines of Punnah, Asiatic Resear. Vol. XVIII, p. 100.
1830.	Hardie, J., Esqr.	Sketch of Geology of Central India, Asiat. Resear. Vol. XIX, p. 281.
1832.	Everest, Revd. R.	On Saline deposits, J. A. S. B. Vol. I, p. 149. Relates to Bundelcund, and Bhurtpur.
„	Prinsep, James, Esq.	Note on the Jubbulpur Fossil Bones, J. A. S. B. Vol. I, p. 149.,
1833.	Benson, Major	Fossil bones from Jubbulpur, J. A. S. B. Vol. II, p. 151. There were from the subtrappean bed at Jubbulpur.

1833. Discovery of a bed of Fossil shells on the Table-land of Central India. J. A. S. B. Vol. II, p. 376.

,, PRINSEP, JAMES, ESQ. Analysis of Coal from near Futehpur (Futtypur) in the Hosungabad district. J. A. S. B. Vol. II, p. 435.

,, EVEREST, REVD. R. Geological remarks made in the country between Mirzapur, and Sâgar. J. A. S. B. Vol. II, p. 475.

,, SPRY, DR., H. Specimens of fossil shells from near Sâgar. J. A. S. B. Vol. II, p. 549.

,, PRINSEP, JAMES, ESQ. Note on fossil bones discovered near Jubbulpur. J. A. S. B. Vol. II, p. 583.

,, SPRY, DR., H. On fossil palms and shells from near Sâgar, J. A. S. B. Vol. II, p. 639.

1834. FINNIS, LIEUT. J. Summary description of the Geology of country between Hosungabad and Nagpur. J. A. S. B. Vol. III, p. 71.

,, SPILSBURY, DR. J. Fossil elephant remains from the Omar Nuddi, near Narsingpur. J. A. S. B. Vol. III, p. 365.

,, SPILSBURY, DR. J. Geological section across the Nerbudda from Tendukheiri to Bittoul, J. A. S. B. Vol. III, p. 388.

1834. PRINSEP, JAMES, ESQ. Note on the fossil bones of the Nerbudda valley. J. A. S. B. Vol. III, p. 396.

1835. FRANKLIN, CAPT. J. On Geology of Bundelcund, Boghelcund, and Districts of Saugor, and Jubbulpore. Geol. Trans. Lond. Vol. III, 2nd Ser., p. 191.—(*Read* 1828, *see also above.*)

,, OUSELEY, CAPT. J. R. Notice of two beds of Coal in the valley of the Nerbudda. J. A. S. B. Vol. IV, p. 648.

,, JACQUEMONT, V. Voyages dans l'Inde pendant les annees, 1828-1832. Paris. fol. 6 Vols.

1836. SPILSBURY, DR. J. Fossil fragment of an acetabulum of an elephant. J. A. S. B. Vol. V, p. 674—also p. 833.

"Too mutilated and indistinct to admit of any inference as to the animal at present," Falconer's Catalogue of Vertebrate Fossils in Museum of Asiatic Society, Calcutta, No. 52.

1837.	Spilsbury, Dr. J.	Notice of new sites of Fossil deposits in the Nerbudda valley. J. A. S. B. Vol. VI, p. 487. (See also p. 321, p. 499, and p. 709 in same volume.)
„	McLeod, Dr. W.	Memorandum regarding specimens from Seoni Chupara. J. A. S. B. Vol. VI, p. 1091. (This district immediately adjoins part of that now reported on.)
1838.	Coal Committee.	Report of, for investigating Coal and Mineral resources of India. No. 1, Calcutta, 1838.
„	Spilsbury, Dr. J.	Note on fossils from Nerbudda. J. A S. B. Vol. VII, p. 91, see also pages 285, 367.
„	Osborne, George.	Report of a visit to the supposed coal field at Bidjeegurh. J. A. S. B. Vol. VII, p. 839.
1839.	Spilsbury, Dr. J.	On specimens of Coal from Lametur ghat, near Jubbulpur. J. A. S. B. Vol. VIII, p. 530.
„	Spilsbury, Dr. J.	On fifteen varieties of fossil shells found in the Sagur and Nerbudda territories. J. A. S. B. Vol. VIII, p. 708.
„	Spilsbury, Dr. J.	On various fossil sites on the Nerbudda. J. A. S. B. Vol. VIII, p. 950.
1840.	Spilsbury, Dr. J.	Notes of a march from Birmhan ghat on Nerbudda, to Umurkuntuk. J. A. S. B. Vol. IX, p. 889.
1841.	Piddington, H.	On the fossil-jaw sent from Jubbulpore by Dr. Spilsbury. J. A. S. B. Vol. X, p. 620.
„	Spilsbury, Dr. J.	On fossil discoveries in the Nerbudda. J. A. S. B. X. 626.
„	Wilkinson, T., Esq.	On the minerals of Nagpore, Calcutta Journal N. History, Vol. III, p. 290.
1842.	Adam, Dr. J.	On the Geology of Bundelcund and Jubbulpur. J. A. S. B. Vol. XI, p. 392.
1843.	Malcolmson, J. S., Esq.	Note on fossil plants, discovered in the sandstone rocks at Kamptee, near Nagpur. J. A. S. Bombay. Vol. I, p. 249.
1844.	Shakespeare, A.	On the navigation of the river Nerbudda. J. A. S. B. Vol. XIII, p. 495. (Not geological, but illustrates the Physical Geography of the river.)

1844. Malcolmson, J. S., Esq. On lacustrine tertiary fossils from the Vindhyan mountains, near Mandoo &c. Jour. Geograph. Soc. Bombay Vol. VI, p. 368.

Spilsbury, Dr. J. Notes on Nerbudda Fossils. J. A. S. B. Vol. XIII, p. 765.

1845. Ouseley, Lieut. Col. On course of the River Nerbudda. J. A. S. B. Vol. XIV, p 354.
(geographical, not geological.)

Abbott, Capt. J. On the occurrence of Granite in the bed of the Nerbudda. J. A. S. B. Vol. XIV, p. 821.
(Relates to a portion of the river not included in our reports).

1846. Coal Committee. Reports of, to May 1845. Calcutta, Fol. 1846.

1847. Piddington, H. On ferruginous spherules imbedded in sandstone in Bundelcund. J. A. S. B. Vol. XVI, p. 711.

„ Keatinge, Lieut. And Lieut. Evans. On a passage down the river Nerbudda. J. A. S. B. Vol. XVI. p. 1104.
(Relates to physical character of the river-channel west of our map.)

1849. Fenwick, Capt. On passage down Nerbudda from Chiculda to Broach. J. A. S. B. Vol. XVIII, p. 461
(Like the last, refers to the physical character of the channel.)

1849. Hamilton, Sir R. On transport of Coal from Sonadeh to Bombay J. A. S. B. Vol. XVIII, p. 594.

1853. Hislop, Revd. S. On geology of Nagpur State. J. A. S. Bombay. Vol. V, p. 58.
Postscript to ditto, p. 148.

1854. Hislop, Revd. S. and Hunter, Revd. A. On the geology of the neighbourhood of Nagpur, Quart. Jour. Geol. Soc. Lond. Vol. X, p. 470—Vol. XI, p. 345.

Jacob, Arthur, A. Reconnaissance of the Nerbudda valley in Central India. Jour. Geol. Soc. Dublin. Vol. VI, p. 183.

Sankey, Lieut. R. H. On the geology of some parts of Central India. Quar. Jour. Geol Soc. Lond. Vol. X, p. 473.

1854.	CARTER, DR. H. J.	Summary of the Geology of India. J. A. S. Bombay. Vol. V, p. 179.
„	HISLOP, REVD. S.	On age of the Coal strata in Western Bengal and Central India. J. A. S. B. Vol. XXIV, p. 347.
	Do. Do.	On the connexion of the Umret coal-beds with the plant-beds of Nagpur, &c. &c. Quar. Jour. Geol. Soc. London. Vol. XI, p. 555.
„	IMPEY, DR.	On physical character of Nerbudda valley, with selections of reports, &c. Selections from record of Bombay Government, No. XIV.
1856.	OLDHAM, THOS.	On results of preliminary examination of Central India. J. A. S. B. Vol. XXV, p. 249.
„	MEDLICOTT, JOS. G.	On Coal and Iron deposits of the Nerbudda. Selections from Records of Government of India, No. X.
1857.	CARTER, DR. H. J.	Contributions to geology of Central and Western India. J. A. S. Bombay. Vol. V, p. 614.
1857.	BLACKWELL, J. H., ESQ.	Report of examination of mineral districts of Nerbudda valley. Selections from Records of Bombay Government, No. XLIV.

In addition to the above, there are several most valuable papers, which refer to the districts adjoining, or near to the Nerbudda, which are not included, such as MALCOLMSON's paper on the fossils of the Eastern portion of the great basaltic district of India Geol. Soc. Lond. Trans. 2nd Ser. Vol. V, p. 537.

SYKES. On a portion of Dukkun, East Indies. *Ibid*— Vol. IV, p. 409, &c. &c.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

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INDIA.

VOL. II.

PUBLISHED BY ORDER OF HIS EXCELLENCY THE GOVERNOR GENERAL OF INDIA IN COUNCIL.

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THOMAS OLDHAM, L.L. D.,

Fellow of the Royal and Geological Societies of London; Member of the Royal Irish Academy; Hon Mem. of the Imperial Academy of Natural Sciences, Breslau; &c. &c.

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PREFACE.

THIS, the second volume of The MEMOIRS OF THE GEOLOGICAL SURVEY OF INDIA, is devoted to papers relating to the geological structure of Central India.

It will be seen, on perusal of these reports, how much information has been added to the previously existing knowledge regarding this important section of the Indian territories; and, further, how materially it has been necessary to modify, and even how totally to alter, the conclusions arrived at by earlier observers. Yet there are few portions of India, (as will be seen by a reference to the following pages,) which have received more frequent, or more careful illustration, than that herein described.

Only those who have been individually obliged to wade through such a series of detached papers, as will be found enumerated in this volume, can realize the feeling of utter disappointment, which grows in intensity as they turn from one to the other, and seek in vain for some common clue to guide them through the maze, some connecting link to bind these isolated facts into some general grouping. And this feeling is only deepened by the thorough conviction, with which they must be impressed, that each and all of these enquirers had honestly and fairly noted down their observations: that there had been no desire to uphold some favorite theory, which might have warped their judgment; no anxiety to disprove the assertions of others, which might have prejudiced their testimony. It is simply this, each was isolated; each detached; there is not even a community of language, such as to enable the student to see that different things have not been described under the same names, or the same things under different words.

If, then, in nothing else, the importance of the accompanying reports will at once be obvious in their reducing to one system all the facts regarding the structure of Bundelcund and of the Nerbudda valley.

I have also, in the present volume, endeavoured to give a summary of the fossil evidence derived from these rocks in Central India, or from their representatives elsewhere, so far as this evidence has been worked out. This has been done, in anticipation of the future publication of all the details, in order, so far as possible, to indicate, if I could not establish, the probable position in the general geological succession, which these groups of rocks, relatively, hold. There is no doubt that much, very much, yet remains to be done, before definite conclusions can be arrived at on such points. And, if it occur to any as an objection to such reports as those now given, that they are detached, and fragmentary, (but no one is so fully alive to the force of this objection, as the authors themselves) it may, I think, fairly be asked that they should remember, on the one hand, the immensity of area over which an Indian Geologist must wander, and on the other hand, the great difficulty of establishing good geological horizons in a new country of such extent. True, there may be on the Western shores of the Peninsula, some beds the epoch of which is tolerably fixed, but this datum is of little use to the investigator whose labours may be confined to the Eastern limits of the same Peninsula, unless there be a knowledge of the intervening country, which stretches over an interval of some twenty degrees of longitude. The Himalya and Sub-Himalya ranges may give a tolerably fixed datum, and still before this can be applied in the examination of the Southern extremity of the peninsula, at a distance of some fifteen hundred miles, the variation in mineral character and in organic contents over this interval of five and twenty degrees of latitude, must be traced out. Moreover, some *general* idea of the relations of the rocks at these far distant points must be obtained before it will be possible to look for any of that exhaustive minuteness of detailed examination, which might fairly be expected at the hands

of a Geological Survey, working among the more limited, the more thoroughly investigated, and therefore, the better known formations, with which European Geologists are familiar.

I confidently hope that it will be possible during the ensuing season to unite this Central Indian work, with the districts already investigated in Bengal. The disturbed state of the country has prevented the accomplishment of this during the last few years. But the connexion between the two once established, many questions of great geological interest, now undecided, will receive a solution.

THOMAS OLDHAM.

March, 1860.

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NERBUDDA VALLEY.

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TO THE READER.

I regret to state that, owing to excessive carelessness on the part of the Lithographers of the accompanying Map, a serious error has crept into it. As this is at an interesting, important, and easily accessible locality near Lameta Ghât, Jubbulpur, a corrected outline is here given of this small portion.

T. OLDHAM.